TRANSACTIONS

The American Fisheries Society

SEVENTIETH ANNUAL MEETING
TORONTO, ONTARIO
SEPTEMBER 5 and 6, 1940

Transactions

of the

American Fisheries Society

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AMERICAN FISHERIES SOCIETY

THE AMERICAN FISHERIES SOCIETY

Organized 1870 **Incorporated 1910**

The Society was organized to promote the cause of fish culture; to gather and diffuse information of a scientific character; and to unite and encourage those interested in fish culture and fishery problems.

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PRESIDENTS' TERMS OF SERVICE AND PLACES OF MEETING

The first meeting of the Society occurred December 20, 1870. The organization then effected continued until February, 1872, when the second meeting was held. Since that time there has been a meeting each year, as shown below. The respective presidents were elected at the meeting, at the place, and for a period shown opposite their names, but they presided at the subsequent meeting.

1.	William Clift	1870-1872	New York, N. Y.
2.	William Clift	1872-1873	Albany, N. Y.
3.	William Clift	1873-1874	New York, N. Y.
4.	Robert B. Roosevelt	1874-1875	New York, N. Y.
5.	Robert B. Roosevelt	1875-1876	New York, N. Y.
6.	Robert B. Roosevelt	1876-1877*	New York, N. Y.
7.	Robert B. Roosevelt	1877-1878	New York, N. Y.
8.	Robert B. Roosevelt	1878-1879	New York, N. Y.
9.	Robert B. Roosevelt	1879-1880	New York, N. Y.
10.	Robert B. Roosevelt	1880-1881	New York, N. Y.
11.	Robert B. Roosevelt	1881-1882	New York, N. Y.
12.	George Shepard Page	1882-1883	New York, N. Y.
13.	James Benkard	1883-1884	New York, N. Y.
14.	Theodore Lyman	1884-1885	Washington, D. C.
15.	Marshall McDonald	1885-1886	Washington, D. C.
16.	W. M. Hudson	1886-1887	Chicago, Ill.
17.	William L. May	1887-1888	Washington, D. C.
18.	John Bissell	1888-1889	Detroit, Mich.
19.	Eugene G. Blackford	1889-1890	Philadelphia, Pa.
20.	Eugene G. Blackford	1890-1891	Put-in-Bay, Ohio
21.	James A. Henshall	1891-1892	Washington, D. C.
22.	Herschel Whitaker	1892-1893	New York, N. Y.
23.	Henry C. Ford	1893-1894	Chicago, Ill.
24.	William L. May	1894-1895	Philadelphia, Pa.
25.	L. D. Huntington	1895-1896	New York, N. Y.
26.	Herschel Whitaker	1896-1897	New York, N. Y.
27.	William L. May	1897-1898	Detroit, Mich.
28.	George F. Peabody	1898-1899	Omaha, Nebr.
29.	John W. Titcomb	1899-1900	Niagara Falls, N. Y.
30.	F. B. Dickerson	1900-1901	Woods Hole, Mass.
31.	E. E. Bryant	1901-1902	Milwaukee, Wis.
32.	George M. Bowers	1902-1903	Put-in-Bay, Ohio
33.	Frank N. Clark	1903-1904	Woods Hole, Mass.
34.	Henry T. Root	1904-1905	Atlantic City, N. J.
35.	C. D. Joslyn	1905-1906	White Sulphur Springs, W. Va.

*A special meeting was held at the Centennial Grounds, Philadelphia, Pa., October 6 and 7, 1876.

36.	E. A. Birge	1906-1907	Grand Rapids, Mich.
37.	Hugh M. Smith	1907-1908	Erie, Pa.
38.	Tarleton H. Bean	1908-1909	Washington, D. C.
39.	Seymour Bower	1909-1910	Toledo, Ohio
40.	William E. Meehan	1910-1911	New York, N. Y.
41.	S. F. Fullerton	1911-1912	St. Louis, Mo.
42.	Charles H. Townsend	1912-1913	Denver, Colo.
43.	Henry B. Ward	1913-1914	Boston, Mass.
44.	Daniel B. Fearing	1914-1915	Washington, D. C.
45.	Jacob Reighard	1915-1916	San Francisco, Calif.
46.	George W. Field	1916-1917	New Orleans, La.
47.	Henry O'Malley	1917-1918	St. Paul, Minn.
48.	M. L. Alexander	1918-1919	New York, N. Y.
49.	Carlos Avery	1919-1920	Louisville, Ky.
50.	Nathan R. Buller	1920-1921	Ottawa, Canada
51.	William E. Barber	1921-1922	Allentown, Pa.
52.	Glen C. Leach	1922-1923	Madison, Wis.
53.	George C. Embody	1923-1924	St. Louis, Mo.
54.	Eben W. Cobb	1924-1925	Quebec, Canada
55.	Charles O. Hayford	1925-1926	Denver, Colo.
56.	John W. Titcomb	1926-1927	Mobile, Ala.
57.	Emmeline Moore	1927-1928	Hartford, Conn.
58.	C. F. Culler	1928-1929	Seattle, Wash.
59.	David L. Belding	1929-1930	Minneapolis, Minn.
60.	E. Lee LeCompte	1930-1931	Toronto, Canada
61.	James A. Rodd	1931-1932	Hot Springs, Ark.
62.	H. S. Davis	1932-1933	Baltimore, Md.
63.	Fred A. Westerman	1933-1934	Columbus, Ohio
64.	E. L. Wickliff	1934-1935	Montreal, Canada
65.	Frank T. Bell	1935-1936	Tulsa, Okla.
66.	A. G. Huntsman	1936-1937	Grand Rapids, Mich.
67.	I. T. Quinn	1937-1938	Mexico City, Mexico
68.	Fred J. Foster	1938-1939	Asheville, N. C.
69.	T. H. Langlois	1939-1940	San Francisco, Calif.
70.	James Brown	1940-1941	Toronto, Canada

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PART I
BUSINESS SESSIONS

TRANSACTIONS

of the Seventieth Annual Meeting of the

AMERICAN FISHERIES SOCIETY

Toronto, Ontario

September 5 and 6, 1940

The Seventieth Annual Meeting of the American Fisheries Society convened at 9:30 a.m., September 5, 1940, at the Royal York Hotel, Toronto, Ontario, the President, T. L. Langlois, of Put-in-Bay, Ohio, presiding.

The meetings were held in cooperation with the Thirty-fourth Annual Convention of the International Association of Game, Fish and Conservation Commissioners.

The registered attendance of members, delegates and guests was as follows:

Registered Members in Attendance

Alderson, I. T., Missouri
Atkinson, C. J., Canada

Bangham, Ralph V., Ohio
Barrett, Paul, Michigan
Beckman, William C., Michigan
Bode, I. T., Missouri
Bonham, Kelshaw, Texas
Bonnet, Luis C., Puerto Rico
Brett, J. Roland, Canada
Brown, James, Kentucky

Carbine, William F., Michigan
Catlin, Mark, Wisconsin (Rep. Wis. Cons. Com.)
Chalk, John D., North Carolina (Rep. N. C. Div. of Game and Inland Fisheries)
Chute, Walter H., Illinois
Clark, Arthur L., Missouri
Clark, Orton Horace, Michigan
Cobb, Kenneth E., Connecticut
Cowden, S. M., New York (Rep. N. Y. Cons. Dept.)
Culler, C. F., Wisconsin

Davis, George W., Vermont
Davis, Lyle L., Texas
Day, Albert M., District of Columbia
Deason, H. J., District of Columbia
Denmead, Talbott, Maryland
Donaldson, L. R., Washington

Fellers, Carl R., Massachusetts
Fiedler, R. H., District of Columbia
Fremont, Charles, Canada
Fry, F. E. J., Canada

Garberson, Ralph E., Iowa (Rep. Iowa Cons. Com.)
Gaunitz, E. B., Iowa (Rep. Iowa Cons. Com.)
Gordon, Seth, Pennsylvania
Gottschalk, John, Indiana
Graves, D. N., Arkansas
Greeley, John R., New York
Greenbank, John, Michigan
Greene, C. W., New York
Gutermuth, C. R., Indiana

Halpin, John L., New York (Rep. N. Y. Cons. Dept.)
Harkness, William J. K., Florida
Hayford, Charles O., New Jersey
Heacox, Cecil E., New York
Henn, Arthur W., Pennsylvania
Herndon, G. B., Missouri
Herrington, William C., Massachusetts
Hoffmaster, P. J., Michigan
Hogan, Joe, Arkansas
Holland, Ray, New York
Hunter, R. P., Connecticut (Rep. Conn. St. Bd. of Fisheries & Game)
Huntsman, A. G., Canada
Hutton, M. L., Iowa

Jacocks, West, South Carolina
James, M. C., District of Columbia
Jobes, Frank W., Michigan

Kennedy, W. A., Canada
Kingsbury, Oliver R., New York

Lagler, Karl F., Michigan
Lang, William, Canada
Langford, R. R., Canada
Langlois, Thomas H., Ohio
LeCompte, E. Lee, Maryland
Lindsay, R. C., Canada
Locke, S. B., Massachusetts
Loutit, W. H., Michigan
Lucas, Clarence R., District of Columbia

McKenzie, R. A., Canada
McLane, William A., Florida
MacKay, H. H., Canada
MacKenzie, H. W., Wisconsin (Rep. Wisconsin Cons. Dept.)
Martin, William Robert, Canada
Markus, Henry C., New York
Menard, Ernest, Canada (Rep. Que. Dept. of Game & Fisheries)
M'Gonigle, R. H., Canada
Moore, Emmeline, New York
Morton, Howard M., Massachusetts (Rep. Plymouth Rock Trout Co.)
Mottley, C. McC., New York

O'Connell, Frank, Nebraska (Rep. Neb. Game, For. and Parks Com.)
Osborne, Lithgow, New York (Rep. N. Y. Cons. Dept.)

Partridge, J. A., Louisiana (Rep. La. Dept. of Cons.)
Pautzke, C. F., Washington
Pearen, H. E., Canada
Poe, J. Charles, Tennessee (Rep. Tenn. Dept. of Cons.)
Powell, A. M., Maryland
Prevost, Gustave, Canada

Quee, Ethel M., District of Columbia (Rep. American Wildlife Institute)

Raney, Edward C., New York
Rayner, H. J., New York
Richard, L. A., Canada
Richardson, A. A., South Carolina (Rep. S. C. Game & Fish Dept.)
Ricker, W. E., Indiana
Roach, Lee S., Ohio
Rodd, J. A., Canada
Roelofs, Eugene W., Michigan

Schultz, Leonard P., District of Columbia
Shawhan, H. W., West Virginia
Shetter, David S., Michigan
Shoemaker, Carl D., District of Columbia
Simmons, N. M., Indiana (Rep. Ind. Div. Fish & Game)
Simon, James R., Wyoming
Smith, Fulcher, Maryland (Rep. Md. Game & Inland Fish Com.)
Smith, Lloyd L., Minnesota
Smith, M. W., Canada
Sprules, William M., Canada
Stack, George F., Pennsylvania
Stephens, E. Sydney, Missouri (Rep. Mo. Cons. Com.)
Stephenson, J. H., Michigan (Rep. Mich. Cons. Com.)
Stiffler, B. F., New York
Swartz, Albert H., Massachusetts

Taylor, B. W., Canada
Taylor, D. J., Canada (Rep. Ont. Dept. of Game & Fisheries)
Thompson, Fred A., New Mexico
Thorpe, Lyle, Connecticut
Trautman, Milton B., Ohio
Tucker, William J., Texas
Tunison, A. V., New York

Underhill, A. Heaton, New York

Vladykov, Vadim D., Canada

Walcott, Frederic C., Connecticut (Rep. American Wildlife Institute)
Wallace, David H., Maryland
Webster, B. O., Wisconsin
Werner, W. H. R., Canada
Westerman, F. A., Michigan
White, H. C., Canada
Widmyer, E. R., Michigan
Wilkinson, J. T., Michigan
Wright, A. H., New York

Young, Earl C., Canada

Registered Guests in Attendance

Bailey, John Wendell, Virginia
Battle, Helen I., Canada
Baxter, William, Jr., Delaware
Bliss, H. C., Canada
Bonham, Mrs. K., Texas
Bowie, T. C., Jr., North Carolina

Cameron, T. W. M., Canada
Cameron, M. C. Adrienne, Canada
Chute, Mrs. Walter H., Illinois
Corn, Margaret, Arkansas
Curran, H. Wesley, Canada

Davies, Douglas M., Canada
Denmead, Carolyn, Maryland
Denmead, Miss E. T., Maryland
Denmead, Mrs. Talbott, Maryland
Detwiler, John D., Canada
Donaldson, Mrs. L. R., Washington
Fiedler, Mrs. R. H., District of Columbia
Ford, Catherine, District of Columbia
Fowlkes, Sam, Louisiana
Frohne, W. C., Missouri

Gabrielson, Ira N., District of Columbia
Gardner, J. M., Canada
Gentry, Glenn, Alabama
Gordon, Phyllis, Pennsylvania
Gordon, Mrs. Seth, Pennsylvania
Graves, Mrs. D. N., Arkansas
Graves, Mary, Arkansas
Graves, Sue, Arkansas
Greene, Mrs. C. Willard, New York

Hambleton, Jack, Canada
Handy, Laurens, Virginia
Herbert, Paul A., Michigan
Hesen, J. W., Jr., West Virginia

Hogan, W. Murray, Tennessee
Hogan, Mrs. Joe, Arkansas
Hogan, Margaret Rose, Arkansas
Hutton, Mrs. M. L., Iowa

Ide, F. P., Canada

Jacocks, Mrs. West, South Carolina
Jobes, Mrs. Frank W., Michigan
Josserand, Guy D., Kansas
Josserand, Mrs. Guy D., Kansas

Kennedy, Allan S., Massachusetts

Landon, Morris B., Missouri
Langlois, Mrs. T. H., Ohio
Larrabee, Lee, Kansas
Larrabee, Mrs. Lee, Kansas
LeCompte, Mrs. E. Lee, Maryland
leMay, T. D., Canada
Lockley, Arthur S., Canada
Loutit, Mrs. W. H., Michigan

McCormac, Fred J., Louisiana
McFarlane, W. D., Canada
Macartney, J., Canada
Macleod, Alexander T., New York
Marshall, Nelson, Florida
Miller, Max J., Canada

Ohsol, J. G., New York

Pearson, T. Gilbert, New York
Phillips, F. Donald, North Carolina
Presnall, Clifford C., District of Columbia

Raney, Charlotte E., New York
Rayner, Mrs. H. J., New York
Rogers, Harold M., Canada
Russell, Carl P., District of Columbia

Schultz, Mrs. Leonard P., District of Columbia
Simon, Mrs. James R., Wyoming
Smith, Mrs. Fulcher P., Maryland
Stephens, J. L., Georgia
Sullivan, M. M., Nebraska

Taylor, Nell, Arkansas
Toner, G. C., Canada
Trautman, Mrs. Milton B., Ohio
Tucker, Billy, Texas

Wallace, Elizabeth M., Maryland
Warren, A. Emerson, Canada
Westerman, Mrs. Fred A., Michigan
Westman, James R., New York
Wilkinson, Mrs. J. T., Michigan

OPENING ADDRESS

T. L. LANGLOIS, PRESIDENT

Some problems of fish management require attention, aside from those involved in raising fish. I refer particularly to the need for improving the relationships of fish-culturists to fishery biologists and of both groups to conservation administrators and to the commercial fishing interests, to sportsmen and to the general public.

The task of keeping supplies of fish available for those who would like to catch them has been considered from many angles, as indeed it needs to be; for the problems involved are complex. Nevertheless they are much simpler than the task of establishing and maintaining the confidence of conservation officials, commercial interests, sportsmen, and the general public in our integrity and ability to do the job. It behooves us so to conduct our activities that we can proceed along such pathways as are indicated by all available facts, and to avoid sidetracks which may develop popular appeal but lack real merit; for backtracking is next to impossible.

Artificial propagation was the keynote for decades, and fish management in which natural propagation receives major attention appears now to be coming into all conservation programs. Funds for fishery activities are derived principally from the sale of fishing licenses, and are necessarily limited. The extension of fishery programs by efforts to improve fish habitats involves either increased expenditures or curtailment of funds spent for other purposes. Since the same funds cannot be spent twice, available funds must be increased to permit the operation of the new functions, or the old functions must be reduced.

It is now generally accepted that while there are places where stocking of fish is called for at times, wholesale stocking programs are apt to do as much or possibly more harm than good. Why, then, are wholesale stocking programs continued? For the simple reason that the purchasers of angling licenses have believed for years that loads of fish placed in angling waters would make better fishing, and they demand that the practice be continued. They express their demands in promises of political support for an administration that will do as they wish, and threaten one that will not. How may the fish-culturist accomplish a shift in emphasis of activities aimed at improving fishing by improving habitat?

In most cases administrators are kept busy adjusting the demands of pressure groups, and are loath to antagonize the powerful groups of anglers who demand the continuance and extension of the old procedures. The fish-culturist must change the nature of the demands of anglers, and may succeed if he has the assistance of the administrators in this respect. Only when the anglers insist that funds be spent for habitat improvement can progress be expected.

The problem, then, is one of effecting a substitution of demands, of helping anglers to relinquish an old point of view and acquire a new one. This involves (1) the development of confidence on the part of anglers in the integrity and ability of the fish-culturists, and (2) the clever presentation of facts regarding both old and new procedures. All of this effort will be wasted if, thereafter, the new policies are not quickly incorporated into an action program which gets results. If demonstrably good results are forthcoming the anglers' confidence will be maintained and their support will be assured for the new activities.

There are several effective types of fish-management activity, the applicability of each varies from place to place. Briefly summarized, they are as follows:

1. The creation of new water areas—headwater reservoirs. These may be considered as a new type of fish hatchery or fish farm from which the fish produced are not distributed to other waters but are taken out by the anglers. This saves the expense of rearing and distribution and the loss of reared fish when placed in new environments. Such new water areas are subject to complete control and the harvest can be limited to production. When built in valleys that once carried permanent streams but now carry intermittent streams, the impounded areas tend to raise the water table and restore permanent stream flow. Reservoirs of this type are important to game as well as to fish and have value for types of recreation other than fishing and hunting. For most effective fish management many reservoirs of somewhat more or less than 100 acres in area are preferable to a few larger ones. I realize that this applies to Ohio and some of the midwestern States like Ohio rather than to states that have multitudes of lakes.

2. The reduction of pollution and the return of polluted areas to conditions suitable for fish production is equivalent in value to creating new fishing areas. The encouragement of land-use practices that reduce silt pollution probably is the most important aspect of this problem, and close cooperation of State fish-culturists with a number of Federal agencies is essential thereto. The construction of farm ponds may be encouraged by laws making such ponded areas free of taxes. The construction of dams across small streams should be discouraged as much as possible because such dams interfere with the movements of fish, and the small streams are of the utmost importance in the production of forage fishes.

Control of industrial pollution has had us all stopped. The enforcement of existing regulatory laws appears to bog down everywhere, and a new approach to the problem seems to be in order. The social and economic problems of the industrial polluter have never been given adequate consideration. In Ohio we are attempting to work with the polluter instead of trying to club him into an action which he resists. We have added an engineer to our staff who knows the chemistry and mechanics of the principal polluting industries—sugar, paper, creameries, oil and domestic wastes. His experiences to date have been gratifying. Conferences with executives of the various industries have resulted in changes of physical equipment and the adoption of procedures that are effectively reducing plant discharges. Instead of conducting another general pollution survey of the entire State, efforts are concentrated on those few places where there are heavy fish mortalities at certain seasons each year. The correction of a few specific instances is more beneficial than the accumulation of more data concerning pollution, and unquestionably promotes better public relations.

3. The fish populations of many water areas are not yielding satisfactory annual crops; in some cases because of unbalances in the ratio of abundance of predator and forage fish species; in others because of excess abundance of one species in proportion to available food supply. The stocking programs of past decades have been aimed at improving fishing by adding many individuals of the desired species, generally predators, while present tendencies are to establish better balances by removing excess predators or adding forage, and, in general, limiting numbers of fish so that the food supply can provide good growth.

In the Ohio lakes and ponds we have concluded that the rate of turnover in stocks is too slow—that our waters are underfished. In controlled areas we have fished intensively, removing the game fishes with nets, and although fearful at first of killing the goose that laid the golden egg, we have each year removed more fish than before, and the average size continues to be very satisfactory. Our netting crews have been used during the past three summers in State-wide surveys which have had a very great influence on public opinion. These crews operate on schedules which enable them to spend from 3 to 5 days

at each of the larger water areas of the State, and to reach each place at approximately the same date each year. Fyke nets are set upon arrival, and anglers and operators of boat liveries and resorts are invited or even urged to be present when the nets are lifted. Complete data are taken on all fish caught, and the fish that have been either tagged or fin-clipped. Although the samples of fish so obtained reflect the selective effects of the fishing gear used, and obviously do not represent more than small sections of the fish population of the entire area, they do provide a comparison of the same area from year to year and of one area with another.

Almost without exception, when our nets are lifted, the onlookers are surprised at the average size and quantity of fish present in their lake, pond or stream, and begin promptly to boast about the good fishing. This leads logically to good will toward the conservation administration and to a cessation of demands for stocking. In one case it demonstrated the possible effectiveness of intelligent stocking, where the sole effort involved planting 53 adult redeared sunfish in a place where it did not occur but where suitable conditions existed. In four years the species became so abundant that good fishing was provided.

4. The creation of new reservoirs and attempts to improve fishing in old ones must involve more consideration of the aquatic plants. The importance of having water areas produce annual crops of those species of leafy aquatics that provide the best shelter and forage conditions is obvious. The productivity of many lakes, ponds, reservoirs and streams could be assisted if methods of producing plant crops were better known. In some areas excess crops of desirable species of plants require control, and more effective methods of harvesting or eliminating such vegetation need to be developed. Possibly these same methods, when developed, could be used to eliminate undesirable species of plants.

In conclusion, there are a few questions which I would like you to consider seriously. In view of our increasing fund of information about fish populations and the natural laws regulating their densities, are our present restrictions on fishing intensity, with sanctuaries, closed seasons, length and bag limits, actually doing any good? If excess production of fry is the rule, should we rigidly protect so much of our brood stock, or should we establish sanctuaries where more of the fry can be helped to survive? If more and better fishing is our goal, should we not seriously consider the removal of as many restrictions on the fishermen as can possibly be consistent with good regulation of fish population densities? How much harm would actually result from removal of most of the existing restrictions? How much good in public support for constructive activities would result from the removal of such restrictions? Possibly we are overlooking a very worthwhile procedure.

REPORTS OF OFFICERS

REPORT OF THE SECRETARY-TREASURER
For the Year 1939-1940

SETH GORDON

The work of the American Fisheries Society has progressed in a very encouraging manner during the past fiscal year, notwithstanding the fact that the number of members dropping out exceeded the new applications. As you have already observed, the 1939 Volume of the *Transactions* has established a new high in quality and usability. The new style of index is certainly a big improvement, and the Committee on Publications deserves special commendation for its painstaking efforts to produce the best volume possible.

In the manner of memberships, the recently adopted policy of dropping promptly from the rolls those who neglect to pay their dues has made it necessary to eliminate almost 100 from membership. These, together with a few resignations and 8 deaths of which we have received notice, bring the total loss to 113. During the same period 72 new members were enrolled, so that our records show a net loss of 41 members. Fortunately we have in hand a number of applications for presentation at this Seventieth Annual Meeting, which will no doubt improve the membership record considerably.

Due to resignations and failure to pay dues, at the end of the fiscal year we had only about 75 per cent of the States enrolled as members in good standing, with none of the Provinces holding membership. However, we are reasonably confident that some of the States that are delinquent will re-establish their active membership status. Since the close of the year we have received applications for such memberships from the States of Georgia and New Mexico, and from the Province of Ontario. We are hopeful that at this meeting additional States and Provinces will apply for membership in order that they may not only obtain the benefits thereof but that they may help maintain an organization which has meant so much to the fishery work of North America during the past 70 years.

At the close of the 1938-1939 fiscal year your treasurer reported a substantial bank balance, namely, $1,549.11 in the General Fund, and $1,020.66 in the Permanent Fund (in addition to investments). However, since the 1938 volume of the *Transactions* and the cost of indexing for that volume had not been paid when the books were closed the cash balance on hand was larger than normal.

During the past fiscal year we not only paid those bills but also paid the printing bill for the 1939 volume. And at the close of the past fiscal year our outstanding indebtedness amounted to only $342.60, of which $327.55 covers the cost of reprints ordered by authors of papers at the 1939 meeting, which will be returned to the treasury with a small profit to the Society on the larger orders. We barely break even on the small orders for reprints.

Our cash balance in the General Fund at the close of the 1939-1940 fiscal year was $396.17. In our Permanent Fund we had to our credit on July 1 a total of $608.68, having invested $750.00 of said fund in U. S. Government bonds in accordance with authorization at the San Francisco Meeting.

The cash balance in the General Fund of the Society as of August 23 was $1,330.59, which is here reported merely as a matter of information. It indicates, however, that since the close of the fiscal year dues have been coming in exceptionally well, and that the prospects for the coming year are encouraging.

Your Executive Committee at a meeting yesterday considered various matters pertaining to the work of the Society, and directed me to report actions taken as follows:

1. *Copies of Programs.*—That in the future the Local Committee on Arrangements be requested to have 725 extra copies of the program for the annual meetings printed and shipped to the Secretary for mailing direct to all members of the Society promptly after the annual meeting as a matter of immediate information, and that in such mailing shall be included the administrative head of each State and Provincial department in charge of fishery work, whether members or not.

2. *Progressive Fish Culturist*—That since it may be wise to consider again a previous offer tendered to the Society and take over the responsibility for the publication and distribution of the *Progressive Fish-Culturist*, now published and distributed gratis to a large list of fishery workers by the Fish and Wildlife Service of the U. S. Department of the Interior, the President be instructed to appoint a committee of three to explore the possibilities and to report its findings and recommendations to the Executive Committee for consideration.

3. *Permanent Library*—That in view of the fact that the Society's permanent library is incomplete, with a total of 10 volumes of its *Transactions* missing, also the desirability of binding two copies of each volume and placing one set thereof in some suitable library, as the property of the Society, where the same will be available to research workers and others interested, it was decided that the Committee on Publications shall be authorized to proceed with plans to duplicate missing copies of volumes as necessary to complete the library and to have all the permanent library volumes suitably bound. Said Committee is to be authorized to draw against the unexpended balances in the Permanent Fund up to $250.00 during the year ending June 30, 1941, vouchers to be subject to the usual prior approval of the President and Secretary before payment.

Your Secretary also would like to suggest that in future years the members of the Society be required to submit the titles of papers at least two weeks in advance of the annual meeting in order to simplify the problem of arranging and printing the programs. Ten days in advance is not enough time to do a satisfactory job.

Now before giving you the financial statement, since your present Secretary-Treasurer proposes to relinquish the position he has filled for the past 10 years, with your indulgence the speaker would like to make a few comments.

A very pronounced change has taken place in the wildlife conservation movement during the past decade. The public has become aroused to the need for husbanding our natural resources, and the increased interest in fishery work has undoubtedly gone far beyond the anticipations of the founders of the Society 70 years ago. One of the striking changes during the decade is the shift in emphasis from fish culture and more stocking to greatly increased research work and the development of sound management practices.

During the speaker's tenure of office the *Transactions* of the Society have been improved most notably; the guide prepared by the Committee on Publications for the preparation and editing of papers has been most helpful to those presenting papers; the number or reprints ordered each year has increased greatly; and the work of the Society has become widely known and accepted in scientific circles.

Notable also among the recent achievements was the development of the American Fish Policy, prepared by a special committee after several years of painstaking effort and adopted by the Society in 1938. This policy has served as a most useful guide in the advancement of fishery conservation programs throughout North America. The important work of both the Committee on Common and Scientific Names of Fishes and the Committee on Pollution also should be mentioned.

I beg to submit the financial statement for the past fiscal year as follows:

TREASURER'S REPORT

June 16, 1939—June 30, 1940

RECEIPTS

GENERAL FUND

Balance on hand June 15, 1939		$1,544.11
Annual dues		
Individuals:		
For the year 1937-1938	$ 30.00	
1938-1939	201.00	
1939-1940	1,020.00	
1940-1941	25.00	
1941-1942	3.00	1,279.00
Libraries		
For the year 1937-1938	$ 2.00	
1938-1939	28.00	
1939-1940	78.00	108.00
Clubs and dealers		
For the year 1938-1939	$ 5.00	
1939-1940	110.00	
1940-1941	10.00	125.00
State membership		
For the year 1937-1938	$ 40.00	
1938-1939	100.00	
1939-1940	440.00	580.00
Exchange on checks		.30
Sale of *Transactions*		341.88
Sale of separates:		
1937 *Transactions*	$ 23.24	
1938 *Transactions*	369.72	
1939 *Transactions*	73.56	466.52
Sale of Index		4.00
Total receipts		$4,448.81

DISBURSEMENTS

Transactions:		
1938, Vol. 68		
Reprints	$ 346.50	
Indexing	105.48	
Printing	1,617.57	$2,069.55
1939, Vol. 69		
Reporting	$ 134.70	
Proofreading	11.20	
Printing	1,190.88	
Indexing	50.00	1,386.78
Clerical and secretarial expense:		
Seth Gordon	$ 100.00	
E. M. Quee	200.00	
Extra assistance	19.25	319.25

Refund for separates and *Transactions*		1.89
Postage		136.14
Exchange on checks		4.73
Stationery and printing		34.61
Rental safety deposit box		5.50
Office supplies		1.84
General expense		4.40
Express		8.80
Premium on bond		18.75
Insurance		13.75
Telephone and telegraph		1.65
Returned checks		45.00
Total disbursements		$4,052.64
Total receipts General Fund	$4,448.81	
Total disbursements General Fund	4,052.64	396.17
Balance on hand, July 1, 1940	$ 396.17	
Balance in Petty Cash Fund	5.00	
Balance on hand July 1, 1940	$ 401.17	

PERMANENT FUND

RECEIPTS		
Balance on hand June 15, 1939		$1,020.66
Interest on Savings Account	$ 12.55	
Interest on Mortgage Certificates	295.47	
Dividends on Commonwealth Southern pfd.	30.00	338.02
Total		$1,358.68
DISBURSEMENTS		
Purchase of Government Baby Bonds		$ 750.00
Total disbursements		$ 750.00
Balance on hand July 1, 1940		$ 608.68
Par value of certificates other than Government Bonds		5,000.00
Par value of 10 shares Commonwealth Southern pfd.		1,000.00
Par value of Government Bonds		1,650.00
Total		[1]$8,258.68

LIST OF AMERICAN FISHERIES SOCIETY SECURITIES

1. New York Title & Mortgage Company Series F-1, guaranteed first mortgage certificate due Sept. 1, 1941, 5½ per cent, interest payable March and September, issued Nov. 2, 1932, Cert. No. 10811, registered in the name of the American Fisheries Society $1,000.00
2. Title Guarantee & Trust Co., guaranteed first mortgage certificate, guaranteed by Bond & Mortgage Guarantee Company, covering south side of Meserole St. between Bushwick Place and Waterbury St., Kings Co., dated Dec. 5, 1927, 5½ per cent interest, payable June 1 and Dec. 1, Cert. No. B-71070, Bond No. 333576, Guarantee No. 180,-205, issued in the name of American Fisheries Society $3,000.00

[1]The market value of Certificates during the past year has been far below par, but since there is no open market no established cash value is available. The cash value of the 10 shares of Commonwealth and Southern Preferred, par value $100.00, as of July 1, 1940, was $592.50.

3. Title Guarantee & Trust Co., guaranteed first mortgage certificate, guaranteed by Bond & Mortgage Guarantee Company, covering Harrell Building Corp., property N/S Ovington Avenue 172.1½ ft. East of 3rd Ave., Brooklyn, N. Y., dated Nov. 9, 1929, 5½ per cent interest, payable June 1 and Dec. 1, Cert. No. 103,553, Bond No. C-7401, Guarantee No. 170,885, issued in the name of the American Fisheries Society		$1,000.00
4. Commonwealth Southern Corp., Preferred Stock, Certificate No. P-50996, dated March 4, 1932, 6 per cent, for 10 shares, par value (Issued in the name of the American Fisheries Society.)		$1,000.00
5. U. S. Government Savings Bonds, Series C, due 10 years from issue date, issued as of Sept. 1, 1938, as follows:		
B454695 C	$500.00	
C1465252 C	100.00	
L943587 C	50.00	$ 650.00
6. U. S. Government Savings Bond, M592089 D[2]		$1,000.00
(All of the above Government Bonds issued in the name of the American Fisheries Society.)		
Par value of all above securities		$7,650.00

THE PRESIDENT: It is my sincere regret that, according to Mr. Gordon, this will be his last report as Secretary. I will entertain a motion to the effect that his report be accepted.

MR. FIEDLER: I so move.

(The motion, duly seconded, was adopted by a unanimous vote.)

THE PRESIDENT: There is a brief report from the Librarian, in which he points out that the volumes have been moving out at about a normal rate. There has been an abrupt stop, he says, in foreign orders since the war started. "The demand for these books had been on the increase for the past few years, especially in the southern and western countries, and I trust will pick up again after the war." Mr. Cobb has submitted a list of the volumes on hand and indicates the volumes needed to complete the permanent library. This list can be examined at the desk if anyone wishes to see it.

I have the following telegram from Germain Bulcke, of the California Fish and Game Commission:

> In behalf of the Fish and Game Commission of the state of California I wish to extend the sincere regrets of the Commission and State that we shall not be represented at your worthwhile convention. Please convey to your members the Commission's and State's good wishes for a successful meeting.

[2]Held by Riggs National Bank for future delivery. All other securities in Lock Box G-315 at Riggs National Bank.

REPORTS OF VICE-PRESIDENTS OF DIVISIONS

REPORT OF THE DIVISION OF FISH CULTURE

M. C. JAMES

This being an election year, your Vice President of the Division of Fish Culture submits a report in accordance with the tradition in that it both points with pride and views with alarm. The pride arises from the fact that fish-culturists have shown increasing progressiveness in perfecting the technology of their vocation. This progressiveness has been demonstrated in devising new improvements under their own initiative and in acceptance of the contributions which have been made by the biologists. Production of trout at a food-cost approximating 15 cents per pound is increasingly common. Hatchery brood stocks demonstrate more and more the streamlined superiority of selective breeding. Diseases, parasites, and their treatment are slightly less obscure problems to us than they were 1 year, or 5 years ago. Plant and equipment more often resembles a well designed, well constructed production unit, rather than a series of afterthoughts.

In pond culture, there is a general acceptance of the thought that a pond, containing brood stock, and fry or fingerlings is not necessarily a fish production unit. Food, be it Entomostraca, forage fish, or artificial diets, has received belated recognition as an element of importance in the breeding of warm-water species. The interaction of starvation, cannibalism and disease in bass ponds, as in trout troughs, have received needed illumination from the studies of Swingle, Meehean, and others. Interesting implications on the artificial manipulation of black bass eggs, and on hormone stimulation of the spawning threshold, have been coming from the State of Wisconsin. Bit by bit there have been coming from divergent sources fragments of information which have ratified the instinctive judgments of the old-timers, and enable us to carry on from where they were forced to leave off. And finally, the more numerous, better and cheaper fish which we can now produce can be transported to their destination in better shape and at lower cost.

Public acceptance of the hatcheries as the whole story in fish conservation is still largely unshaken. The shad fishermen of the East coast and the Great Lakes commercial fishermen still call for more hatcheries as the shot in the arm that will needle their industry to a new life. State and Federal fishery administrators are all aware of the perennial blooming of concerted drives for new game-fish hatcheries, and are painfully familiar with the fact that such unwanted projects may be thrust upon them at a time when needed support for other existing facilities is unobtainable. In fact, fish-culturists may have oversold themselves, and it is at this time that I ask your indulgence for one minute in order that I may change the reel and start viewing with alarm.

We may as well recognize the fact that some of the more advanced advocates of the management theory of fish conservation wrinkle or hold their noses at the mention of hatcheries. Comments of a few of them would indicate that, in their estimation, the only good hatchery is one which has just been taken over by a fire-insurance adjuster under the total-loss clause in the policy. Others hold that the hatcheries might be useful if they were run on some different basis, which basis often has only the remotest relation to current financial and other practicalities. This viewpoint is sure to reach the public attention. We all recognize that the public attitude on conservation matters is a most active pendulum swinging from one extreme to the other. It is not in the least inconceivable that the present public indorsement of hatcheries may go into a reverse swing which will leave hatcheries, their personnel and friends high and dry, and, in my opinion, jeopardize an institution which is the backbone of

fishery management in anything but a primitive, undeveloped, sparsely populated country.

This danger is more imminent if the public does not receive the full picture with all its shadings and perspectives which will be laid before us at this and succeeding meetings of this Society.

Reports of negative results in the stocking of a few test streams here and there are valid data and deserve consideration. Conditions in the streams and lakes of New Jersey and Connecticut are valid data also, unless you hold that two other States should have been set up as control experiments so that we could determine by box-score rating the real standing in that gripping contest: "Nature vs. Charley Hayford."

Stream surveys are made, and there is much discussion of the waste of fish, through improper planting both as to species and numbers. If I were a fishery administrator and could not find the thousands of dollars necessary to finance a single season's program of stream survey, I might consider the possibility of obtaining some make-shift data by making an experimental and "wasteful" plant of a few thousand hatchery fish costing me all of $150. Furthermore, stocking programs formulated as a result of stream surveys have, in certain instances reported to the speaker, revealed a stocking demand for certain species, at least, in excess of the current productive capacity of the hatcheries serving the area. John Q. Public should know all this.

John should also know that exhaustive investigations on means of preserving the Columbia River run of salmon were made by biologists who were free to call the plays as they saw them. Their findings were reviewed by an impartial Board of Consultants. These findings put the burden of the job, for the next 10 years at least, on the shoulders of the hatcheryman. It is more than a good bet that the situation will be duplicated when a report is finally rendered covering a similar problem on the Sacramento River. And this is a type of fish-cultural work from which the hatcherymen were gradually withdrawing because they couldn't prove their own case.

When questioned concerning the efficacy of stocking warm-water fish in large river systems, hundreds of miles in length, or in large lakes, tens of thousands of acres in area, I hang my head and blush and stutter like a shy, sweet schoolgirl. But what of these thousands of vest-pocket ponds, pools, reservoirs, and lakes which are being constructed with public funds or with public aid and encouragement? These are the ideal areas for management practices and they will not synthesize their own fish. Stocking must come from some source. Guess where!

Fish-culturists have made their mistakes and those mistakes are rising up to meet them with all the impact of an 80-ton tank. However, there has already been demonstrated the adaptability which will void most of the mistakes of the past, and which will permit adjustment to the future scheme of things. There must be a decision as to where the functions of the hatchery man cease and where those of the management begin. If the latter merely exercises a privilege of criticism or veto, or merely outlines his plan and ideas of how matters should be handled, thereafter washing his hands of the whole question, we are in for an extended period of argument and bickering. Even so, this argument will be chiefly as to methods, details, and ways and means. If the impression gets out that the discussion is a critique as to whether the artificial propagation of food and game fishes is really justifiable, or serves any real purpose, both sides will suffer. The management people will be deprived of a factor vital to them in the prosecution of their work and the fish-culturist will become the living personification of "The Little Man Who Isn't There."

None of these things need come to pass if competent administrators rap a few heads together, strike a balance of the services available from the respective groups, and let judgment and common sense direct the activities of both fish-culturists and biologists of the management school.

MR. JAMES: It has occurred to me, since hearing the comments of Dr. Langlois and Mr. Gordon, and observing the trend here, that sooner or later we shall have to give thought to the possibility of obtaining a first-class specimen of what has been delicately termed the old-line fish-culturist and having it either stuffed or pickled and kept as a mascot or emblem of the past history of the organization. It may be premature to consider that now, but the time may come when it will be the appropriate thing to do.

THE PRESIDENT: Thank you, Mr. James, for such an excellent presentation. It is obvious that we are all thinking along somewhat similar lines; we are impressed with the necessity of working together. I do not think it should be so difficult. I believe the old-line fish-culturist definitely has a place in the picture. After all, he is the one who does things. Most of the modern fish-management people, the biologists, are primarily fact-finders. They are finding a lot of facts which have been somewhat disconcerting. The obvious thing to do about it, I think, is to incorporate your old-line fish culturist into the actual practice of modern fish management as we see it. Certainly a sympathetic attempt to see the point of view of both sides should work to the mutual benefit of all concerned.

REPORT OF THE DIVISION OF PROTECTION AND LEGISLATION

I. T. QUINN[1]

Only nine State legislatures met in regular session in 1940; several had special sessions. There is therefore not much legislation to report for this off-legislative year. The Federal legislation covered by this report will be limited to three major measures and a brief resume of other legislation, most of which is pending. The usual run of bills were introduced, making changes of no particular importance so far as accomplishing anything in conservation is concerned, but causing some confusion.

Montana's Commission recommended that the open season for fishing be shortened by 4 months because of water conditions below normal. Its adoption will still leave an open season from May 21 to November 15, against which no angler should register a kick.

Indiana abolished its separate license for trout fishing.

New York dropped the 10 pounds per day limit on trout and reduced the number of trout per day from 15 to 10. The Department of Water Supply, Gas and Electric Company temporarily prohibited fishing in its watershed lakes and streams on account of the war scare. The same action was taken in regard to Conowingo Dam, Maryland, but these orders were later modified.

Missouri shortened its open seasons on black bass and trout by 15 days, extended the open season on channel catfish 2 months, and changed the squirrel season, formerly from August 1-December 31, to June 15-October 31. Someone ought to write a history some day of the frequent changes in squirrel seasons which in some States are altered at nearly every other legislative session. Missouri is still having its troubles by attacks on the constitutionality of its Commission Act. It is a sad spectacle to see the efforts of a real conservation commission attacked by a gang seeking special privileges.

Idaho opened the trout season 30 days earlier than formerly, although the tendency in most States now is to open at later dates.

Alabama established a closed season on black bass for the first time; it becomes effective after January 1, 1941, for the reason that licenses and laws were issued before the passage of the act. This leaves only three states without a closed season on the black basses, namely Louisiana, Oklahoma and South Carolina.

Tennessee reduced the daily catch of crappie from 20 to 15, with a 9-inch size

[1]Read by Talbott Denmead, in the absence of Mr. Quinn.

limit. (We wish the Southern States would stop calling this fish "white perch.") It also tried to stop the sale of black bass from Reelfoot Lake by the promulgation of a regulation, but the Attorney General ruled the Commission did not have the authority to take this action.

Colorado shortened the open season for trout by 14 days.

Ohio lowered the creel limit on black bass from eight to six.

A Georgia judge contended that no anglers' licenses are required to permit any person to fish in private ponds, and warned the game wardens—rangers in Georgia—they would get into a lot of trouble if they made any arrests. I'll put my money on the present up-and-coming Georgia authorities to "scotch" that kind of stuff in short order.

Petitions were circulated in Colorado to insure a place on the ballot for a constitutional amendment to put the State Game and Fish Commission beyond political influence. More power to them, but many of us would like to know how they plan to accomplish this.

Maryland has a constitutional amendment on its ballot this fall in order to permit the State to decide whether it wants a Chesapeake Bay Commission of paid practical fishermen to administer the laws affecting fish, crabs and oysters.

Federal Legislation.—The following is a brief synopsis of bills introduced, and mostly pending, in the Congress of the United States during the past year:

H. R. 68.—Relating to trespass on wildfowl refuges.

H. R. 931.—For an addition to Ottawa National Forest.

H. R. 5236.—To establish a reservoir in Bear River, Utah, to maintain water levels on the Bear River Migratory Bird Refuge.

H. R. 5590.—To authorize the acquisition of certain lands in Montana and construct dams for the Woody Island Wildlife Refuge.

S. 685.—The Barkley Pollution Bill.

H. R. 2961.—To establish Green Mountain National Park in New Hampshire. There are a number of persons who believe this proposal lacks merit on the ground that the area is not of National Park caliber.

H. R. 3841.—For a highway through Bechler Meadows, Idaho, into Yellowstone National Park.

H. R. 6975.—Calls for the return of 2,500 acres of Yellowstone Park to the State of Montana for undisclosed purposes.

S. 207.—Would permit prospecting and location on National game preserves.

S. 3532.—Would provide boards of local stockmen to advise the Secretary of Agriculture with respect to administration of grazing lands in National forests.

S. 3611.—To permit baiting waterfowl.

H. R. 69.—To amend Migratory Bird Stamp Act to include all migratory game birds.

H. R. 4832.—To give protection to the American eagle. This bill was passed and has been signed by President, and it is now illegal to kill eagles in every State.

H. R. 6321.—The Buck bill. This is a fish bill and of interest to all members of the American Fisheries Society. Briefly the bill is drafted along the lines of the Pittman-Robertson Act. It provides for a 10 per cent tax on fishing tackle, the funds obtained therefrom to be apportioned among the States for fish restoration. This bill has been widely publicized and it seems unnecessary to refer further to it in this report, except to say it is still in Committee and likely to stay there the remainder of this session.

REPORTS OF STANDING COMMITTEES

REPORT OF THE COMMITTEE ON INTERNATIONAL RELATIONS

A. G. HUNTSMAN

This Committee reviews the relations of the countries represented in the Society (the United States, Canada and Mexico) with each other and with neighboring countries. With the whole world upset by the international strife that has involved such large parts of Europe, Asia and Africa in recent years, it is a relief to be able to record continuing good relations in the North American field, with which our Society is concerned.

However, the involvement of France in war during the summer of 1939 resulted in cessation of the activities of the *North American Council on Fishery Investigations.* This Council, which has been in existence since 1921, has served as a medium for the annual interchange of information concerning the state of, and the work related to, the oldest international fishery of the western hemisphere. Before the successful settlement of this continent by Europeans, fishermen from the countries of western Europe were making annual fishing voyages to the prolific oceanic banks of the western North Atlantic, as those of France and Portugal continue to do. While in former centuries these fisheries were the subject of international disputes, in this century the North American Council, with representation from the United States, Canada, Newfoundland and France, has been coordinating investigations of the region by these countries in order that the common object of making them as productive as possible may be more quickly achieved.

The fisheries on the Pacific with a shorter history of development and with interests less firmly established as a consequence, provide outstanding examples of international co-operation and control. The *fur seal industry* of Bering Sea and the Pacific Ocean formed a subject of controversy between the United States, Canada, Russia and Japan for many years. By the Pelagic Sealing Treaty of 1911 between Great Britain and the United States, Canada abandoned pelagic sealing north of 35° N. Lat., in lieu of receiving one-fifth of the annual take of seal-skins at the Pribilof Islands in Bering Sea, where these animals breed. The Treaty involved an agreement by all four countries to prohibit pelagic sealing in waters frequented by the fur seals. The arrangement permits a better utilization of the stock by confining the killing to the seal rookeries, where there can be a suitable selection as to age, sex and number.

The halibut fishery of the Pacific coast has also come under international regulation through the creation in 1924, by convention between the United States and Canada, of the *International Fisheries Commission.* It undertook a very thorough investigation of the fishery and its background and has for some years been applying the regulatory measure of limiting the amounts to be taken each year from particular grounds. As a result, the decline in catch that had been taking place was arrested and the catch per unit of effort has on the whole increased very considerably. It is expected that increase in the spawning stock will in due time increase the annual additions to the populations of halibut of marketable size. A definitely upward trend in the numbers of eggs and larvae gives good ground for this expectation.

After a rather long preparatory history, the *International Pacific Salmon Fisheries Commission* was established in 1937 by Canada and the United States for the protection, preservation and extension of the sockeye salmon fisheries of the Fraser River system. It has been given the power of limiting or prohibiting the taking of sockeye salmon in specified waters related to the Fraser River, and of regulating the character of the fishing gear used on the high seas, and from May to October in territorial waters. A thorough investigation is in progress.

Over a long period, the United States and Canada have from time to time at-

tempted to cooperate in common regulation of the fisheries in the territorial and contiguous waters of the two countries. Under an agreement made in 1892 between the United States and Great Britain a Joint Commission of two experts was appointed for this purpose in 1893 and reported in 1896. Again a convention concluded between Great Britain and the United States in 1908 resulted in the appointment of an International Fisheries Commission of two persons, one from each country, which prepared and recommended the adoption of "a system of uniform and common international regulations for the protection and preservation of the food fishes in international boundary waters of Canada and the United States." But these were not adopted. It may be that an attempt to settle summarily the question of proper fishery measures for a great variety of species in the most varied waters along a boundary line of more than 3,000 was bound to fail. In any event, with the examples of the oceanic and somewhat remote fur seal and halibut investigations before them, the fishery interests at the western extremity of this boundary are now attempting to settle one of the many thorny international fishery problems that it presents through a commission that is dealing with one species of fish, the sockeye salmon, in one river system, the Fraser, by thorough scientific investigations covering a long period of years.

Toward the eastern end of the boundary, there has been a similar attempt to reach "a permanent solution of the problems upon the basis of co-operative conservation measures" for a particular fishery in a limited area involving the States of New York and Vermont and the Province of Quebec. The *Missisquoi Bay-Lake Champlain Joint Scientific Fact-Finding Commission* was appointed in 1929 for the pike-perch fishery and game fish conservation in Lake Champlain waters, and its inquiries and field work were completed in 1931. Its report has not yet been presented, so that the outcome is in doubt.

The most recent attempt to solve fishery problems of the boundary covers the broader field of the Great Lakes. Our Society owes its inception largely to concern over decreases in the fisheries of this region, in which this year's meeting of the Society is being held. For more than 60 years there has been agitation for international action, since it was realized that to a greater or less extent the stock of fish is a common one, which can be successfully handled only by joint action. There have been many varied attempts in recent years to make progress with the matter mainly by conferences between the States involved, of which there are eight in all, and the Province of Ontario, which borders all the Great Lakes on the Canadian side.

As the outcome of a unanimous resolution adopted by such a conference, held in 1938 at Detroit under the auspices of the Council of State Governments, representatives of the Governments of the United States and of Canada agreed in February, 1940, to the establishment of an *International Board of Inquiry for the Great Lakes Fisheries.* This Board is to "make a study of the taking of fish in the Great Lakes," to "make a report of its investigations to the two Governments" and to "make recommendations as to the methods of preserving and developing the fisheries of the Great Lakes." The appointments to this Board were by the United States, Mr. Hubert R. Gallagher, Assistant Director, Council of State Governments, and Dr. John Van Oosten, in charge Great Lakes Fishery Investigations for the U. S. Department of the Interior, Fish and Wildlife Service; and by Canada, Dr. A. G. Huntsman, Consulting Director, Fisheries Research Board of Canada, and Mr. D. J. Taylor, Deputy Minister of Game and Fisheries for Ontario. An organization meeting was held at Toronto on April 15 and 16, 1940, at which Mr. Gallagher was made Chairman and Dr. Huntsman, Secretary, and a scientific advisory committee was constituted consisting of fishery investigators of the region. There are to be public hearings at some of the principal places on the Great Lakes.

There are reasons for believing that uniform regulation of certain fisheries along the coast of the Gulf of Mexico on either side of the boundary between the United States and Mexico might result in larger yields for both countries from the stock of fish there which is more or less a common one. An international commission to investigate and determine the facts would seem to be justified.

A review of the results of past attempts at international co-operation for improvement of the fisheries justifies the conclusion that success in such co-operation is dependent upon (1) selecting a particular fishery for concentrated attention, and (2) conducting a thorough scientific investigation, perhaps over a long period of years.

DR. HUNTSMAN: There is an old saying that a fool learns by his own experience, a wise man by the experience of others. In this matter of international co-operation affecting the fisheries there are constantly new people coming in, so that there is no possibility of a fool learning by his own experience. Whether we shall be called wise or not may depend upon whether we can or cannot correctly read history.

I am not certain what should be done in this case; it may be that the Society should be asked to pass upon such a conclusion by the Committee, or if it can be accepted merely as a report setting forth an obvious conclusion, no particular action may be necessary. It is this: the Committee recommends to the Society that its name be changed to "Committee on International Relations" as being properly descriptive of its character.

THE PRESIDENT: The Committee on Resolutions is asked to consider Dr. Huntsman's proposed change in the name of the Committee, and to bring in for consideration of the membership a resolution amending the by-laws of the Society.

REPORT OF THE COMMITTEE ON COMMON AND SCIENTIFIC NAMES OF NORTH AMERICAN FISHES

WALTER H. CHUTE

The Committee on Common and Scientific Names of Fishes, of the American Fisheries Society, is attempting to arrive at a list of common names of the more familiar fishes of North America which will be acceptable to the majority of biological workers on this continent. It is expected that such a list, if used by writers and fishery workers in general, will help eliminate much of the confusion now existing in popular nomenclature.

It is the present plan of the Committee to select one official name for each fish, with a very few exceptions such as California sardine and pilchard. This official name will be printed in large type with the present accepted scientific name. All other names proposed, unless deleted by a two-thirds majority, will be printed in small type as secondary or unofficial names. To make the list more readily available to laymen, it has been suggested that it be published in alphabetical order by common names, with reference on each secondary name to the official name. This matter has not been definitely decided as yet.

To start the project the Chairman prepared a preliminary list of names which was mailed in March, 1939, to the various committee members. Some of the committee members sent copies of this list to workers in their respective territories and asked them for comments and suggestions. From the corrected lists returned the Chairman made up a revised list representing the opinions of fourteen correspondents. The original list contained a total of 439 names of fishes. Additional names proposed by correspondents have raised this to a total of 587. Certain members of the Committee suggested additional workers throughout the United States and Canada who should be consulted. There are now 30 collaborators working on the lists. The second lists were prepared and mailed in July, and contained in addition to the names proposed the remarks of the various collaborators on those names on which controversy has arisen. Up to the present time 11 of the revised lists have been returned to the Chairman and contain 40 additional proposed names.

The Chairman made special trips to Washington and to Ann Arbor, Michigan, in connection with this work, but most of it is carried on by correspondence and is necessarily very slow. Of the 627 names on the list a little more than 50 per cent have been unanimously accepted. There have been from two to four names proposed for most of the remaining fishes on the list. In most cases there has been an overwhelming majority in favor of one name, but in view of the importance of this work, the Committee feels that no name should be selected until the opinions of the objectors have been set before the other collaborators. It seems apparent that it will be impossible to arrive at a unanimous opinion on the entire list. It is felt, however, that when the final vote is taken, that name favored by a two-thirds majority of the 30 collaborators will bear the weight of authority.

In general, the response to invitations to cooperate in this work has been very gratifying and many opinions as to the desirability of such a standardized list have been expressed. The Chairman has been informed that the Sears Foundation of Yale University is preparing a cooperative monograph on "The Fishes of the Western North Atlantic," as far south as the mouth of the Amazon. The editing board in charge of this work has asked the collaborators to use the common names adopted by the American Fisheries Society Committee on Common and Scientific Names of Fishes. A similar work is envisioned for the Pacific coast as far south as Panama, and those interested have informed the Chairman that should such a work be attempted, they will also adopt the common names advocated by the American Fisheries Society.

It is probable that before this work is completed two more revised lists will have to be sent out. It is hoped that next fall a list containing only those names still in controversy can be prepared and as soon as returns from this list are received a final complete list will be sent out for approval of committee members before being submitted to the Society. It is sincerely hoped that the final list will be ready for the 1941 meeting, but the committee feels that before a final list is submitted sufficient time must be given for a thorough discussion of the many controversial names on the list. It is obviously impossible for any list containing one official name for each fish to satisfy everybody. However, inasmuch as all other names proposed will be listed as unofficial names, it will be readily usable in all sections of the territory covered, and it is believed that most, if not all, of the official names will in time gain unanimous recognition.

In closing this report I would like to quote from a letter received from Dr. J. R. Dymond, Director of the Royal Ontario Museum of Zoology: "This is a most important work and being done at a critical time. The average angler and the average educated man is taking an interest in an ever-widening number of species of fish, and demanding names for them. This tendency will continue and we should be ready with names which we believe are suitable to be fixed permanently on the different species. If we are convinced that a name is definitely unsuitable *now* is the time to attempt to change it; it can be more easily done now than at any future time. We should not hesitate to *attempt* to change names which are obviously unsuitable. We may fail but if we do, no great harm has been done, but if we do not make the attempt there is no chance of succeeding."

The Chairman agrees heartily with the opinions expressed by Dr. Dymond and begs the indulgence of the Society to the end that this work may be thoroughly discussed and that the completed lists will bear the weight of authoritative opinion.

THE PRESIDENT: Mr. Chute's committee is to be complimented upon the amount of work it has done in this matter. It is probably one of the most important undertakings the Society has under way, and should by all means be carried through to completion.

MR. GORDON: One of the things that the completion of this list will do will be to furnish a guide not only to administrators and fishery workers but also to press and magazine writers—and these are the ones who are reaching the general public. When you consider how very much misused the names of many of our fishes are in the average outdoor magazine or the average press column, it is no

wonder that the general public does not understand. As soon as this list is available the Outdoor Writers Association, of which I happen to be a member, will certainly adopt it as a guide, and I think we can get most of the newspaper columnists who are writing on outdoor topics to do the same.

The adoption of such a list as a guide, particularly by those who are reaching the general public, will do much to eliminate the confusion which now prevails in the public mind with regard to the names of fishes. While on a fishing trip in Canada during the week prior to the opening of the Convention I noticed that the local guide talked about "pickerel"; and even the camp operator, who has travelled all over Canada and the United States, used the same name. I said: "Just what do you mean?" "Well," he said, "you may call it susquehanna salmon, or wall-eyed pike, or pike-perch, but we call it pickerel up here." This use of different names for the same fish is prevalent in respect to a great many other species. So that when we have a guide of the kind which this list will provide it will not be long before the general public, in referring to particular species of fish, will use names that everybody will understand.

DR. A. H. WRIGHT (Cornell University): Within the last few years I have been making a study of reptiles, and I have been over all the common names of reptiles used in the popular literature since the discovery of America. This question of common names is a very complicated one. Let me illustrate: In the earlier history of the United States, before the development of the country farther west, the common rattlesnake was known in the east as the eastern rattlesnake, while the Iowa rattlesnake was known as the western. As time went on and settlement extended farther west you can see the confusion that would be caused by the fact that the Iowa rattlesnake was already commonly known as the western variety. So that current usages vary with the passage of time, and we ought to think in terms of local usage in each region, not as we transplantees from other regions think the common names ought to be determined. It is obvious that this committee has a job which must be carried on over a considerable period of time.

THE PRESIDENT: With regard to the Committee on American Fish Policy, I discussed this matter with Mr. Wickliff before leaving Columbus, and he indicated that he had no comments to make or changes to propose as a result of anything done during the last year. He recommends that the Committee be disbanded. Mr. Gordon has a number of reprints of the American Fish Policy as adopted in 1938 and they will be available to members who would like to have them.

In view of the recommendation of the Chairman I will entertain a motion that the Committee be thanked for its valuable services and discharged.

(On motion of Dr. Schultz, seconded by Mr. Denmead, and agreed to by the members present, the Committee on American Fish Policy was discontinued and the members thanked for their services.)

REPORT OF THE COMMITTEE ON PUBLICATIONS

JOHN VAN OOSTEN[1]

I trust that the Society will forgive a certain amount of complacency in this my final report as chairman of the Committee on Publications. The task of raising the editorial standards of the *Transactions* has been difficult. Although the members of the committee worked hard and patiently, it appeared for years that the maintenance of a high standard for the volume would have to depend entirely on their efforts. Only last year I complained rather bitterly at the lack of cooperation on the part of authors who submitted manuscripts for publication. I pointed out that authors not only neglected to follow the most elementary instructions as to arrangement and mechanical details but that frequently they employed such illogical and confusing wording that committee members were forced to rewrite

[1]Read by Dr. H. J. Deason, in the absence of Dr. Van Oosten.

large portions of their papers. It can not be said that all these difficulties have been overcome. I can report, however, that the quality of the manuscripts was improved sufficiently last year to permit the completion of the editorial work with much less effort and several months earlier than in preceding years. I believe that the improvement in the manuscripts is reflected clearly in a better printed volume.

The battle has by no means ended, nor will it ever end. Difficult as it was to raise the standards of the *Transactions*, it will prove only slightly less difficult to maintain them at a high level. It is not enough that members appointed to the Committee on Publications have the ability to edit manuscripts; they must be willing to exercise that ability to its fullest extent. There is no place for the committee member who takes his work lightly, who feels that a mere leafing through a manuscript is good editing. The slightest relaxation of effort is certain to result in a deterioration in the quality of the *Transactions*.

Turning to an entirely different matter, I wish to report at this time the results of a questionnaire distributed last year by the secretary soliciting the opinions of members of the Society relative to the publication of a subject index of the *Transactions*. Members were asked first as to the desirability of publishing an index for the years 1929-1938 (or 1939), second, if they would buy a copy of the index when it was ready for distribution, and, third, whether they would prefer a composite index in the volume of all *Transactions* from 1872 to the present. Replies were received from 170 members, most of whom answered all three questions.

The members favored overwhelmingly the publication of a subject index for the *Transactions* of 1929 and later years. Only 11 per cent expressed opposition to the project as compared with 89 per cent who favored it. Furthermore, 88 per cent of those who filled out the questionnaire stated that they would purchase a copy of the index when it was ready for distribution. The vote was rather close on the third question; 55 per cent favored the composite index and 45 per cent were opposed.

It is the recommendation of the Committee to the Society that a subject index be published for the *Transactions* of the years 1929-1939. We oppose, however, the publication of a composite index covering the years from 1872 to date. Our opposition to the composite index is based principally on two considerations. It should be pointed out that the Society has on hand a supply of the indexes for the years 1872-1928. If these indexes are made unsalable through the publication of a composite index the organization will suffer a considerable financial loss. There is a possibility also that a composite index, because of its higher price might not be sold as readily as the shorter index. We believe, too, that the index for the more recent years should follow the style inaugurated in the 1939 volume (Volume 69). This type of index cannot be combined with the index of the earlier *Transactions*.

The publication of an index for the years 1929-1939 cannot be accomplished without the services of a professional indexer. The task is far too great to be assigned to any member or members of the Committee. We recommend, therefore, that the Society authorize the employment of a professionally trained individual who shall prepare the index, working under the immediate supervision of the chairman.

Finally, I should like to make a suggestion concerning the arrangements for the indexing and proof-reading of future volumes of the *Transactions*. I believe that last year's experiment in having the proof-reading and indexing done under the direct supervision of a committee member (Dr. Deason) has yielded such excellent results that this procedure by all means should be continued. This phase of the Committee's work could be facilitated greatly if funds were allocated for direct expenditure by the Chairman for the services of competent proof-readers and indexers. I recommend, therefore, that the Society place at the disposal of the Chairman of the Committee on Publications an amount adequate to meet the necessary costs of proof-reading and indexing. A review of the expenditures for these

services in past years indicates that an allotment of $125 will be sufficient. This amount should defray also the costs of postage, express, and stenographic services in connection with the editorial work.

THE PRESIDENT: Thank you, Dr. Deason. There is a recommendation that a major job of indexing be done by professional persons, but there is no estimate of cost. Do you know, Dr. Deason, whether the committee went into that question?

DR. DEASON: We did not go into it. Until an opportunity is afforded to go through the cards that are on file in Washington and see what shape they are in and determine whether or not they can be used by being re-edited, or whether the entire series will have to be re-indexed on the new basis, I do not think it will be possible to arrive at any estimate of cost.

THE PRESIDENT: Perhaps, then, we should simply instruct the Committee on Publications to present an estimate at the earliest possible date.

DR. DEASON: I would recommend that. From my experience with the indexing work this year I do not believe that that job can be done in a hurry. In the interests of uniformity the whole job will have to be done by one person, and therefore we should proceed slowly. Until the committee has had an opportunity to go into the matter I would not be prepared to make suggestions or recommendations.

THE PRESIDENT: I would like to entertain a motion that the Auditing Committee be instructed to include in their report a recommendation that the Committee on Publications have a fund not to exceed $125 placed at their disposal for current use.

(Upon motion of Dr. A. G. Huntsman, seconded by Dr. Emmeline Moore, and agreed to by the Society, the Auditing Committee was so instructed.)

REPORTS OF SPECIAL COMMITTEES

REPORT OF THE POLLUTION STUDY COMMITTEE

TALBOTT DENMEAD, *Secretary*

It may interest some of you to know and others to recall that the Pollution Study Committee of the American Fisheries Society was created at the last meeting held in the Dominion of Canada, at Montreal, on September 14, 1934. The Committee therefore completes its sixth year of existence at this seventieth annual meeting which is being held at Toronto. The President of the Society was, by resolution, requested to appoint the committee, limited to 15 members. Senator Harry B. Hawes was selected as its first chairman. Dr. M. M. Ellis succeeded him as chairman several years later. The Committee has had the same secretary since its formation, and I suggest that if the Committee is continued it is time to change secretaries.

In the absence of the chairman, the first report was made by the secretary at the Tulsa meeting in 1935. It was primarily a report on anti-pollution bills then pending in Congress, mostly on the Lonergan Bill. The report, which was adopted, recommended in its conclusions that a further study be made of the pollution problem, with "a view to the recommendation of some method of control not yet agreed upon by the various interests and organizations involved."

A year later, again the secretary reported, in the absence of the chairman, at Grand Rapids, Michigan. The report stated that a majority of the members of the committee were in favor of some form of Federal control as the solution. The report was accepted and a resolution was adopted recommending Federal legislation along certain lines; all five points covered by the resolution were embodied in the Lonergan Bill then pending.

Since that time the secretary has made annual reports as to the progress of Federal anti-pollution legislation. The Committee has never been instructed to make any scientific investigations, nor has it done so. It is quite evident from the record that its functions were non-scientific; it was formed to devise ways and means to stop pollution, not to ascertain what pollution is or what waters are polluted—a gigantic task.

At the Asheville meeting in 1938 the Committee was assigned the job of following up the question of Federal control and legislation, which assignment your secretary tried to carry out to the best of his ability. At the San Francisco meeting in 1939 he reported on the Federal legislative situation, and the Society adopted the report and passed a resolution endorsing Congressman Karl E. Mundt's bill, H. R. 6723. I therefore submit a brief report on the status of the Mundt Bill and Federal control of pollution.

The so-called anti-pollution bill filed by Senator Barkley (S. 685), which cleaned up no pollution but provided for appropriations of a million dollars a year for 10 years for further investigations, passed the Senate. It was believed by many who are interested in actually cleaning up or stopping some pollution to be nothing more than a smoke-screen. In the meantime Congressman Mundt's bill, approved in principle by the American Fisheries Society, remained inactive. Omitting for the sake of brevity the various steps, it is sufficient to report that the Mundt Bill was finally abandoned and amendments were attached by Congressman Mundt to the Barkley Bill in the House. There were two amendments, one declaring pollution of our waters a public nuisance, which is the first time the Federal government has acknowledged its responsibilities in connection with pollution of navigable waters; and the other that "no new sources of pollution either by sewage or industrial waste, shall be permitted to be discharged into navigable waters of the United States and streams tributary thereto until and unless approved by the Division" (of Water-Pollution Control set up by S. 685).

I quote Congressman Mundt from the *Congressional Record* of July 8, 1940, on the last-mentioned amendment:

> "The language of the amendment is so moderate that no restrictions could be made against pollution of any kind in any more reasonable terms unless the polluter's dream is to be realized and this body [the House] is to publicly endorse all pollution practices and declare itself as favourable to the indiscriminate expansion of the pollution evil in all virgin streams and by all devices and systems as yet unknown to man."

The House agreed with Congressman Mundt, passed the Barkley Bill with the Mundt amendments, and sent it to conference. Incidentally, the million dollars a year appropriation for 10 years for investigations was cut to $250,000 per annum. The Senate and House conferees met several times and failed to agree on the House amendments. Congressman Mansfield, under privileged resolution, then took the Bill back to the House and asked that the House conferees be instructed to recede from supporting the amendment. By a vote of 199 to 154 the House reaffirmed its approval of the Mundt amendments, which is Sub-section D of Section 2, thus declining to instruct the conferees to recede.

The Bill now, at last information, awaits a vote in the Senate with the amendments. Friends of the measure hope it will receive approval of the Senate as amended; if not they hope the bill will be killed.

So far as your secretary has been informed, there have been no other important developments or new state laws for suppressing or cleaning up pollution during the past year, worth recording in this report. Incidentally, only nine legislatures met in regular session in 1940.

Now, I am not a scientist, but I have a few comments to offer for which I am indebted to others; biologists well-acquainted with the subject of pollution and its relation to aquatic life.

Previous reports presented to this Society have indicated the need for education in pollution matters. Too few people appreciate the relationship that exists between domestic and industrial pollution and aquatic life. There is a general lack of knowledge of the essential and fundamental fact that public-health standards of water purity are not the same for aquatic life. Pure drinking water may be and often is a biological desert; water that constitutes an ideal medium for the support of aquatic life frequently is unsuited for domestic uses. The methods used to render water supplies potable actually may render the water unfit for fishes and other aquatic organisms.

Standards of water quality for domestic water supplies were set up many years ago and upon these foundations water-treatment plants and sewage-disposal plants have been planned and constructed. Standards of water quality for fishes are still in the process of formulation—a few years ago none existed with any degree of definiteness. The discussion of water quality for fresh-water fishes published in the Third Report of the Special Advisory Committee on Water Pollution (National Resources Committee, 1939) indicated that a set of standards is now available, at least in a broad, general sense and will be more clearly defined at the conclusion of researches now in progress. The toleration of many fishes for most of the common inorganic and organic constituents of industrial wastes is known. Effective measures for the elimination or nullification of most of those wastes have been determined experimentally.

To be genuinely effective in the preservation of aquatic life, pollution control must go far beyond the present-day practice of merely eliminating new sources of contamination or preventing further contamination from old sources. It has been proven that the accumulated partially soluble, insoluble or decaying trade wastes on the banks and bottoms of streams, lakes and artificial impoundments constitutes a threat to the preservation of aquatic life as long as they are allowed to remain. Actual removal of incrustations of chemical or putrifying materials should be attempted. If on land, the accumulated wastes should be excluded from the water. If they are not excluded they will continue to menace aquatic life through the action of rains, freshets, or even normal seepage. The periodic

epidemics of fish mortality that occur in many parts of the country are traceable to such causes in many instances. But, since the epidemic subsides after a time, the flood of complaints diminishes as suddenly as it began. Nothing is done to prevent future recurrences and no progress results.

The relation of pollution to aquatic life and the widespread effects of pollution have not been widely publicized. If they had been, the program of control would be much nearer fulfillment at the present time. Those who have been charged with the investigation of specific problems of industrial and domestic pollution frequently have completed studies, made recommendations and the reports have been filed and, apparently, forgotten. A few years later complaints may be received relating to the same problem, indicating that nothing has been done by the State, Municipality or responsible industrial organization to act upon the recommendations of the previous investigation. Such apathy should not be allowed to continue. Investigating agencies should cease to retain their findings and recommendations in confidence. The general public should be reliably informed concerning the conclusions of every investigation, for it is becoming increasingly apparent that only concerted pressure on the part of the general public will lead to the necessary pollution-removal program, especially on the part of industrial organizations.

Fortunately the domestic sewage menace is being removed by the construction of disposal plants and more and more of these are being completed each year. The financial assistance rendered by the P.W.A. and W.P.A. has enabled a great many communities to construct adequate plants with a minimum drain on their own resources.

The previously mentioned report of the Water Resources Committee disclosed that, in 1939, serious deficiencies existed in the pollution laws of 33 states and that in only 10 states do the conservation officials have any regulatory control over pollution. If pollution abatement is to be in the interest of preserving our aquatic resources in addition to maintaining potable domestic water supplies, conservation officials should have a part in the formulation of legislation, programs of control, and in the enforcement of pollution laws.

Before adequate consideration can be given to pollution control in relation to fish life there should be a change in the personnel of responsible agencies, State boards, sanitary commissions, etc., so that conservation interests will be represented. The technical assistance and advice of an aquatic zoologist or physiologist is essential if pollution-eradication programs are to conform to the broad principles of multiple use of water resources. Water must serve all of the uses that it may, but no one use should be permitted to destroy the potentiality for other uses. On the basis of prior use the fish had the water first, but actually they are receiving last, if any, consideration in far too many instances. It has been demonstrated that the interests of industry, public health and aquatic life can exist in harmony with relation to the same water resource as a result of proper planning. There are many members both of the International Association of Game, Fish and Conservation Commissioners and of the American Fisheries Society who are in a position to do something about pollution.

I will conclude this report with the suggestion: Let action be our watchword!

THE PRESIDENT: In my opening talk I made brief reference to the procedure in Ohio at the present time with regard to pollution. I would like to elaborate on that just a little.

What authority there is in Ohio to control pollution is vested in the State Board of Health. The pollution must definitely be detrimental to public health before they can take action. This authority has not been used. Cases have been repeatedly carried through to the logical conclusion, and all the facts made available to the State Board of Health, without any action resulting. The engineer whom I mentioned earlier as having been appointed to our division was a gold miner. He had been an industrialist; he had been vice-president of a large Chicago corporation, so that he could talk to industrialists on their own

terms. He knows the chemistry as well as the mechanics of most of the polluting industries. He is soft spoken and has a pleasing personality. His ability to sit down with the people in charge of corporations responsible for pollution and talk the matter over with them, emphasize the importance to public relations of conserving the fish and the feasibility of modifying the plant so as to change this picture has resulted in more progress being made in Ohio in the control of pollution during the last year than had been made in previous 20 years—and yet we have absolutely no authority to do anything.

I recognize that we are fortunate in having a man with that combination of background and talent, but possibly there are others who might be available and who could proceed in the same way. All I can say is that it is a technique that is workable.

DR. DEASON: I believe a motion is in order to continue the committee for another year. I so move, subject to any changes in the membership deemed advisable by the President.

(The motion was seconded by Mr. M. C. James and received an affirmative vote.)

APPOINTMENT OF COMMITTEES

Pollution Study Committee

Kenneth A. Reid, *Chairman*, Illinois
Carl D. Shoemaker, Washington, D. C.
Milton P. Adams, Michigan
C. M. Baker, Wisconsin
Charles A. French, Pennsylvania
Thomas Gallagher, Ohio
S. B. Locke, Massachusetts
J. A. Rodd, Ontario
Henry B. Ward, Illinois

Auditing Committee

C. R. Gutermuth, *Chairman*, Indiana
Karl F. Lagler, Michigan
Kenneth E. Cobb, Connecticut

Committee on Resolutions

R. P. Hunter, *Chairman*, Connecticut
D. N. Graves, Arkansas
G. B. Herndon, Missouri
Fred A. Thompson, New Mexico
James Brown, Kentucky

Committee on Nominations

H. J. Deason, *Chairman*, Washington, D. C.
Ralph V. Bangham, Ohio
C. W. Greene, New York
H. C. Markus, New York
F. A. Westerman, Michigan

Committee on Time and Place

Emmeline Moore, *Chairman*, New York
Charles O. Hayford, New Jersey
Lee S. Roach, Ohio
Joe Hogan, Arkansas
S. B. Locke, Massachusetts

Program Committee

Lloyd L. Smith, Jr., *Chairman*, Minnesota
B. O. Webster, Wisconsin
R. H. Fiedler, Washington, D. C.

Special Committee to Consider the Progressive Fish-Culturist

M. C. James, *Chairman*, Washington, D. C.
J. R. Greeley, New York
F. A. Westerman, Michigan

Committee on Publications

Following the Seventieth Annual Meeting, President-Elect Brown appointed Dr. Justin W. Leonard, Lewiston, Michigan, to the Committee on Publications for a term of 5 years, to succeed Dr. John Van Oosten, Ann Arbor, Michigan, whose term had expired. Dr. H. J. Deason, Washington, D. C., was designated as the new chairman to succeed Dr. Van Oosten. The membership of the Committee is as follows:

	Term expires[1]
Dr. Justin W. Leonard, Lewiston, Mich.	1945
Dr. H. J. Deason, *Chairman*, Washington, D. C.	1944
Dr. Ralph Hile, Ann Arbor, Mich.	1943
Dr. Lauren R. Donaldson, Seattle, Wash.	1942
Dr. Paul R. Needham, Palo Alto, Calif.	1941

DISCUSSION OF PROGRAM POLICY FOR FUTURE MEETINGS

THE PRESIDENT: Perhaps I may be permitted at this stage to call attention to a matter in connection with the number of papers on the program and the effect of this large number of papers upon opportunities for discussion.

In many cases the discussion that followed the paper was at least as valuable as the paper itself, but our program has been so full that we have just not had time for this valuable type of discussion. A few years ago we used to have 3 days for our programs, meeting with the commissioners as we still do; the commissioners would take 2 days and we would have 3 full days for fishery papers and discussions. The one-day meeting with the Director of the Fish and Wildlife Service takes over one of our days, and our papers have been limited to 2 days.

There is a limit to what we can cover in 2 days. There are over 60 papers on the printed program, and I have just been handed a list of 6 additional ones, so that the total is nearer 70 than 60. I suggest that a limit be placed on the number of papers to be received for inclusion in the program. It seems to me that a maximum of 20 a day, or a total of 40 for 2 days, is just about as much as we should be expected to cover, and with that number we could have some time for discussion.

Since there is a problem involved of submitting papers in time so that preparation of the formal program can be expedited, I think it would be well if the Society instructed the Secretary to receive for inclusion in the program a maximum of 40 papers, the first 40 titles sent in, with instructions simply to refuse more. It does seem to me that if something of this kind is done our meetings will be much more valuable and the whole process will be expedited.

MR. GORDON: May the out-going secretary add a suggestion to that? It is this: that if there are not 40 papers in, the list be closed two weeks in advance of the opening day, regardless. There should be two limitations, one that the number of papers shall not exceed 40, and the second, that the list positively must be closed two weeks prior to the opening of the meeting.

THE PRESIDENT: I would like to hear discussion on this point.

[1]Indicates the annual meeting at which the term of each member of the Committee will expire.

DR. MOTTLEY: I think the thing is more deep-seated than that. What we need is a journal with about six issues a year; then we could throw our meetings open for symposia or discussion and the exchange of ideas. You cannot get the meat out of one of these papers when it is presented merely in abstract form; you have to wait until the *Transactions* are published before you can really get it. What we need is a journal.

THE PRESIDENT: That is being considered at the present time; a special committee was appointed to deal with it. But until something of that sort is evolved I think some such proposal as I have suggested might be in order.

MR. GORDON: The special committee appointed to consider the question of the continuance of the *Progressive Fish-Culturist*, and whether the Society should in some way take over that responsibility, consists of M. C. James of the Fish and Wildlife Service, John Greeley of New York, and Fred Westerman of Michigan. I suggest that if any of you have any ideas on this subject you should communicate them to this committee in addition to expressing them here.

DR. HUNTSMAN: In order to bring the matter definitely before the meeting for vote, I move that the secretary be instructed to place on the program the first 40 papers that are proposed for the meeting and that are to be read. Perhaps we should ask that the authors be prepared to read them; and that additional papers be read by title.

THE PRESIDENT: Are you prepared to include in that motion Mr. Gordon's suggestion that the receipt of titles should terminate 2 weeks before the meeting?

DR. HUNTSMAN: Yes.

DR. BANGHAM: I will second that.

DR. UNDERHILL: The suggestion is that the number of papers be limited to 40. Will the *Transactions* still be open to additional papers?

DR. HUNTSMAN: That would be the sense of my motion—that the additional ones, beyond the 40 stipulated, be read by title only.

DR. WRIGHT: Why not do as several other organizations do—just put in these papers and put in the topic by title, and then it will be known definitely that certain papers are not going to be read. If people want recognition of certain work that they are doing, in such a way that it might appear in the *Transactions*, then they would definitely say whether they were coming or not. But in the cases to which I refer the title would appear in the program, the paper not to be read.

MR. GORDON: You mean to say that you would list the first 40 papers for presentation, with a separate list of those to be read by title only, the captions to be indicated in the program?

DR. WRIGHT: Yes.

DR. FELLERS: Many who submit papers think they are coming to the meeting but something happens to prevent them from attending. As the Secretary has indicated, a period of 2 weeks should be ample to permit them to make up their minds whether they are coming or not. It seems to me it would be an improvement if in the absence of any definite word from the authors as to their intention to be present, the paper should be automatically read by title.

THE PRESIDENT: Do you care to offer that as an amendment?

DR. FELLERS: I would ask if the mover would care to have that as part of his motion.

THE PRESIDENT: Do you care to accept that, Doctor Huntsman?

DR. HUNTSMAN: I understand the suggestion is that unless there is assurance from the author of the paper that he will be present to read it, it will be read by title. I shall be glad to accept that.

THE PRESIDENT: Is there any further discussion?

DR. LAGLER: I suggest that some judgment should be exercised as to the papers which are to be presented, rather than that they should just be taken in chronological order. One group of workers in one institution might well get in the first papers and there might be a preponderance of papers from one restricted area of the country.

THE PRESIDENT: Yes, there is that possibility.

MR. GORDON: Perhaps I might say a word on that point. Yesterday, for example, we had three papers which interlocked. If it had been possible for those workers to get together and consolidate their findings into a paper of joint authorship which would tell the whole story, the work of the Society would have been facilitated. As a matter of fact these three papers really were one, and unless they appeared together in the *Transactions* you would be looking at several different papers. Workers might keep in mind the desirability of joining forces in the presentation of a paper covering a particular subject rather than taking two or three bites at it.

THE PRESIDENT: I think we can assume that our secretary will use some judgment in this matter, and when he gets a large number of papers from one place he will probably receive only a few of them.

MR. FIEDLER: I understand that in former years the meeting occupied a period of 3 days, and that during the past 2 or 3 years 1 day has been devoted to a get-together between the Fish and Game Commissioners and the Fish and Wildlife Service.

MR. GORDON: That is right.

MR. FIEDLER: I wonder if the Director of the Service would not be willing to relinquish that day so that we might have one more day for the Society.

THE PRESIDENT: I think it is desirable to have that day devoted to that purpose. I should be reluctant to see that change made.

MR. GORDON: My observation has been that it is very hard to keep together a group of fishery workers for 3 days and in addition to keep the administrators at the meetings in sufficient numbers in order that they may learn some of these scientific facts that a lot of you boys have been digging out. Speaking as one of them, I can say that they need that type of information very badly. If the meetings are not strung out too long you can hold some of the administrators in your meetings, and that in turn helps you with your work; whereas if you have a dearth of administrators in the group they begin to look upon your work as something entirely foreign to theirs, as something not as closely related as it really is. That, I believe, is another phase of this same problem that you ought to keep in mind.

THE PRESIDENT: For years the two organizations have alternated in priority of meetings, one coming first in the week one year and second the next year, and so on. It never takes the commissioners longer than 2 days to complete their sessions, and that leaves a third day open for the mid-week conference. If the procedure were to be reversed, and the American Fisheries Society were to meet always at the beginning of the week, taking the first 3 days, the commissioners could meet the last 2 days, with the Saturday following devoted to the Fish and Wildlife Service meeting, we could get the whole thing in and the commissioners would still be there for the Federal and State coordination meetings. But they probably would not come early enough to attend some of the fishery meetings, as they now do.

MR. GREENBANK: I agree with Dr. Lagler that mere chronological priority is not a suitable basis for selecting papers to be presented on the program. I am loath to suggest any alternative method, but at the same time I should hate very much to see an important paper denied admission to the program simply because it happened to be the forty-first one submitted.

DR. MOTTLEY: There was one point in my previous remarks which I should like to emphasize. If you have a journal issued say six times a year the papers will all find an outlet in due course. Where a paper is presented among a large number which are hurried through, it is not possible for the listener to appreciate the full significance of the paper; he has to sit down with it and examine it carefully and in detail. I think he would get more out of these meetings if various subjects of importance were treated in the form of symposia, because people will sit and listen to discussions in which ideas are being exchanged. If the discussion is organized around a few key contributions by outstanding men in certain fields you will get far more interest at the meetings than you will by a dead pres-

entation of papers of which it is impossible for the audience to get the significance when they come in a rush one after the other.

DR. GREELEY: May I correct a possible misunderstanding about the function of this committee that has been appointed? It is not, as I understand it, to consider the publication of a journal; it is merely to decide upon the policy of the Society with regard to the *Progressive Fish-Culturist*—a processed bi-monthly publication with which all of you are familiar. As I understand it, it was considered worth while to inquire into the status of this publication, to see whether it will be continued in its present form or whether there is any way in which the Society can or should participate. That is all this committee is doing; so that the matter of a scientific journal is still entirely open.

THE PRESIDENT: I am still inclined to think that the motion as made by Dr. Huntsman, seconded by Dr. Bangham and amended by Dr. Fellers is a pretty good way of taking care of the present situation without too radical a change in policy. Is there any further discussion?

DR. M'GONIGLE: The program this year has been divided into different sections —Commercial Fisheries, Fish Culture and Stocking, Fish Management, Parasites and Diseases, Research, and so on. I agree with the principle that a maximum of 40 papers should be established, but would it not be well to provide that the fish-culturists should have say the first 20, parasites and diseases 5, and so on, to insure that important papers on a particular subject should not be crowded out because they did not happen to be included in the first forty. There would be an allotment, in other words, of certain important topics; and that would meet, it seems to me, the idea suggested by Doctor Mottley.

DR. WRIGHT: You will soon be coming to the section idea—having one section meet in one place and another in another, as is done in so many scientific meetings.

THE PRESIDENT: I suggest we try out this limitation to 40 papers for the first year, with the understanding that they will be sub-divided into general topics as they have been this year, leaving the actual division to the judgment of the secretary. At the end of another meeting we may decide that it is not a good system, or at any rate we may think it necessary to make radical modifications, but the purpose of course is to effect an improvement over the crowded condition of the program that we have had with the numerous papers presented this year.

(The motion, duly seconded, was voted upon and adopted.)

DR. HUNTSMAN: I suggest that consideration be given to the possibility of publishing abstracts in the program, which might facilitate the handling of meetings and give rise to some interesting discussions. I am not certain how that would work in this society, but it has worked successfully in some others.

REPORTS OF COMMITTEES

AUDITING COMMITTEE

MR. C. R. GUTERMUTH: Your Auditing Committee has checked the books of the Society, also the supporting vouchers, for the period June 15, 1939, to July 1, 1940, and finds the treasurer's report as submitted to be correct. This Committee recommends that the appropriations for the fiscal year 1940-1941 be as follows:

For clerical and stenographic services, exclusive of expenses incident to the preparation, proof-reading and indexing of the *Transactions* of this meeting, the same as heretofore, namely $350.00.

To the Committee on Publications, $125.00, payable to the Chairman in a lump sum on proper voucher to cover cost of proof-reading, indexing, clerical assistance, postage, and incidental expenses, in connection with the 1940 volume of *Transactions*.

From the Permanent Fund, not exceeding $250, for the use of the Committee on Publications in duplicating missing volumes of the *Transactions* and binding two copies of each volume for the permanent library of the Society, payable upon presentation of proper vouchers.

I move that the report of the Committee be approved.

(The motion was seconded by Major Brown and the report adopted.)

COMMITTEE ON TIME AND PLACE

(The following report was submitted by the Joint Committee on Time and Place of the International Association and the American Fisheries Society):

The Joint Committee on Time and Place met in the Royal York Hotel. Dr. Emmeline Moore acted as Chairman and P. J. Hoffmaster acted as Secretary.

Present: Doctor Emmeline Moore, of New York; L. S. Roach, Columbus, Ohio; Joe Hogan, Lonoke, Arkansas; S. B. Locke, Boston, Mass.; and Mr. Charles Hayford, Hackettstown, N. J., for the Fisheries Society; Hoyes Lloyd, Ottawa, Canada; F. B. O'Connell, Lincoln, Nebraska; E. Lee LeCompte, Baltimore, Maryland, and P. J. Hoffmaster, Lansing, Mich., for the International Association.

The Committee first heard persons or delegations bidding for the 1941 conference. Following were the name of States represented and persons appearing before the Committee.

Messrs. McCormac, representing the Sportsmen of that State; Partridge, Executive Secretary, Louisiana Conservation Commission, and Sam Folks, of the Chamber of Commerce, all urged that the 1941 conference to be held in Louisiana. Stress was laid on the need of a good and sound conservation department in Louisiana and they claimed this conference would materially aid in the establishing of such a department.

William J. Tucker of Texas and Major James Brown of Kentucky both appeared in favor of New Orleans as the next meeting place.

Promises of clerical help for registration, etc., printing of programs, rooms gratis for officers and meetings were made by the Louisiana representatives.

Minnesota was represented by Lloyd L. Smith, Jr., of Minnesota Department of Conservation, requesting that next year's meeting be held in St. Paul. He pointed out that St. Paul had many fine parks and other worthwhile things, and adequate hotels. In the event that St. Paul could not be selected he favored St. Louis.

Sydney Stephens, Chairman of the Missouri Conservation Committee, with Morris B. Landau, assistant manager of the Convention Bureau of St. Louis, appeared in behalf of St. Louis as the next meeting place. It was pointed out that this city is centrally located; that they have adequate accommodations and that the Missouri Commission were in a position to aid materially in working out a helpful program.

They assured adequate clerical help, good publicity, rooms gratis for officers, printing of programs and all of the usual facilities and assistance furnished by other cities or states.

New Mexico was represented by Mr. Fred Thompson, Director of Fisheries for New Mexico. He stated the New Mexico Conservation Commission and Governor join him in his invitation to hold the 1941 meeting in that state. Assurance was given that the state would furnish such facilities and assistance as is usually furnished by a state.

Commissioner Poe and William J. Hogan mentioned several good reasons for holding the 1941 meeting in Nashville, Tenn. One was the T. V. A. dam and the conservation accomplishments in connection therewith. Another was the Parthenon replica and other things with cultural value. Mr. Hogan pointed out some sixty-five persons of influence and position join him in his invitation.

Attention was called to the fact that the 1941 meeting of the National Wildlife Federation was scheduled for Tennessee.

Assurances were given that the usual services and assistance furnished by other states or cities would be furnished by Tennessee.

Wisconsin was represented by the Director of the Department of Conservation, Mr. McKenzie, who urged that the 1941 meeting be held in Madison, Wisconsin. This city, he pointed out, was centrally located, which should assure a good attendance; they have some unique things in their state which would be of benefit to the conference.

The Association was assured clerical help, printing and such other assistance as is usually furnished by other states.

No other delegations were present, but there were invitations received and considered from the following other places:

Atlantic City, N. J.
Boston, Mass.
Chicago, Ill.
Alaska.
North Carolina.
Washington, D. C.
Pennsylvania.

Seattle, Washington, wrote in favor of St. Louis.

After further discussion and consideration an informal secret ballot was taken. St. Louis received six votes and three other cities each one.

Also there was informal discussion as to the date. There seemed to be a strong feeling against having the meeting at a time during which there would be a legal holiday.

It was moved by Mr. Lloyd, seconded by Mr. Roach, that the 1941 meeting of the International Association of Game, Fish and Conservation Commissioners and the American Fisheries Society be held in the city of St. Louis, Missouri, during the week August 25th to 29th.

The motion was passed unanimously.

There being no further business the meeting was adjourned with leave for dissolution of the committee.

P. J. HOFFMASTER,
Secretary.

COMMITTEE ON RESOLUTIONS

MR. R. P. HUNTER: Your Committee on Resolutions presents the following resolutions for the consideration of the Society:

1. Amendment to the By-Laws

WHEREAS, There is at the present time a growth of fishery practices, problems, and programs of an interstate nature and of a nature that require coordinated action of State and Federal Governments, and

WHEREAS, It is a vital duty of the American Fisheries Society to provide a common ground for the discussion and planning of programs in regard to fishery matters.

BE IT RESOLVED, That a new standing committee be established in the American Fisheries Society, to be known as the Committee on State and National Relations, to consist of a chairman and four additional members to be elected by the Society, said committee to act as a coordinating and advisory board for the consideration of interstate and National-State fishery problems.

(Upon motion, duly seconded, the resolution was voted upon and adopted unanimously.)

2. Amendment to the By-Laws

WHEREAS, The Committee on Foreign Relations of the American Fisheries Society is concerned primarily with international fishery problems, relations, and treaties among the nations of the American Continents, rather than with problems and relations foreign to the Americas,

BE IT RESOLVED, That the name of the Committee on Foreign Relations be changed to Committee on International Relations, and that the membership, duties and privileges of said committee continue in the same manner as heretofore.

(Upon motion, duly seconded, the resolution was voted upon and adopted unanimously.)

3. The Progressive Fish-Culturist

WHEREAS, The Progressive Fish-Culturist is of recognized value to workers engaged in fish conservation activities.

BE IT THEREFORE RESOLVED, That the American Fisheries Society go on record as favoring the continuation of this publication and that a copy of this resolution be sent to the Secretary of the Interior.

(Upon motion, duly seconded, the resolution was voted upon and adopted unanimously.)

4. Federal Water Power, Irrigation, and Flood Control Projects

SINCE the Bureau of Reclamation and the Fish and Wildlife Service of the Federal Government are now both administered by Department of the Interior, and a correlation of all values in the construction and operation of irrigation dams is now possible, the attention of Secretary Ickes is drawn to the important service which may now be rendered in the screening of diversion ditches, the regulation of flow and water levels in the maintenance of projects under the jurisdiction of the Bureau of Reclamation.

BE IT RESOLVED, That the secretary of this Society be authorized and directed to send a copy of this resolution to the Secretary of the Interior, directing his attention to this important problem.

(Upon motion, duly seconded, the resolution was voted upon and adopted unanimously.)

5. Federal Aid in Fish and Wildlife Restoration

WHEREAS, the Federal Aid in Wildlife Restoration Act, enacted by the Congress of the United States of America, commonly known as the Pittman-Robertson Act, has enabled the several States of the Union to undertake numerous highly desirable wildlife restoration projects which otherwise would have been impossible, and,

WHEREAS, the Federal officials in charge have been most cooperative in their efforts to aid the several states to take full advantage of the provisions of this program, and have studiously avoided any semblance of Federal domination or interference with State rights; and,

WHEREAS, A similar program to aid in the restoration and increase of fish life would be of vast benefit to all the states of the United States of America;

NOW, THEREFORE BE IT RESOLVED, That the American Fisheries Society in seventieth convention assembled in the city of Toronto, this 6th day of September, 1940, urge the prompt enactment of legislation similar to that in H. R. 6321, known as the Buck Bill.

BE IT FURTHER RESOLVED, That at the first opportunity the Pittman-Robertson Act hereinbefore mentioned be amended to include within its provisions authority to expend a reasonable percentage of Federal-aid funds for the maintenance of such projects as may have been established under its provisions, and;

BE IT FURTHER RESOLVED, That the provisions of and the benefits to be derived by the States under the Pittman-Robertson Act and under the proposed Buck Bill be extended to the Territories of Alaska, Hawaii, Puerto Rico and other extra-continental possessions of the United States by the requisite Congressional action.

BE IT FURTHER RESOLVED, That the Secretary of the Society be authorized and instructed to transmit copies of these resolutions to Congressman Frank Buck of California, Congressman A. Willis Robertson of Virginia, Senator Key Pittman of Nevada, to the Director of the Fish and Wildlife Service of the U. S. Department of the Interior, and to the conservation administrators in the several States.

(Upon motion, duly seconded the resolution was voted upon and adopted.)

6. Barkley Pollution Bill

WHEREAS, The pollution of the waters of the United States is harmful to wildlife environment and detrimental to the economic welfare of the people.

NOW THEREFORE BE IT RESOLVED, That this Society again urge the passage of such legislation as contained in the Barkley bill with Mundt amendments;

AND BE IT FURTHER RESOLVED, That the Secretary be authorized to transmit copies of the resolution to Senator Barkley, Congressman Karl Mundt, the press, and all others he deems advisable should be informed of this action.

(Upon motion, duly seconded the resolution was voted upon and adopted.)

7. Appreciation of Courtesies

WHEREAS, THE AMERICAN FISHERIES SOCIETY, in its visit to Canada has been graciously entertained, and

WHEREAS, The members of the Society have been shown every possible courtesy and have been given every possible assistance that might add to the success of the convention and the comfort of the members;

RESOLVED, That this society expresses its appreciation and thanks to the Canadian National Exhibition; the provincial government of Ontario, especially the Hon. H. C. Nixon, D. J. Taylor, deputy-minister; Dr. H. H. MacKay, all of the Department of Game and Fisheries; the city of Toronto; and the capable and hospitable management of the Royal York Hotel.

(Upon motion, duly seconded the resolution was voted upon and adopted.)

8. Commendation of Retiring Officers

SINCE, It is the desire of the Society to recognize the faithful service rendered by the retiring officers, all are tendered the sincere thanks of the organization.

WITH, EXCEPTIONAL GRATITUDE, the Society recognizes the contribution of Mr. Seth Gordon, who retires this year after a decade of uninterrupted service as Secretary.

THEREFORE, BE IT RESOLVED, That this organization express its appreciation and thanks to Mr. Gordon for his loyal and unremitting effort in forwarding the aims of the Society.

(Upon motion, duly seconded the resolution was adopted by a unanimous rising vote.)

MR. WESTERMAN: Mr. President, I wish to move further that, because of the long, faithful, and untiring services Mr. Seth Gordon has rendered to the Society in the capacity of Secretary-Treasurer during that past 10 years, he be extended the privilege of honorary membership in the Society.

(The motion, duly seconded, was adopted by a unanimous rising vote. Applause!)

MR. GORDON: Thank you, sincerely, one and all! I have not earned it, but I will keep on working for the Society.

9. Doctor Edward A. Birge

WHEREAS, DOCTOR EDWARD A. BIRGE, former Professor of Zoology at the University of Wisconsin, President Emeritus of the University of Wisconsin, for many years Director of the Wisconsin Geological and Natural History Survey, a life member of the American Fisheries Society since 1897, and President of the Society in 1906-1907, celebrates his eighty-ninth birthday on September 5, 1940, and

WHEREAS, As administrator, educator, scientist and philosopher he has contributed immeasurably by his researches, writings, teachings and wise counsel to the development of the sciences of fresh-water biology, pure and applied limnology, and fish culture, and to the material advancement of the cause of Conservation,

THEREFORE, BE IT RESOLVED: That the American Fisheries Society, on the occasion of its Seventieth Annual Meeting at Toronto, Ontario, on September 5 and 6, 1940, join with his colleagues, students and friends assembled at Madison,

Wisconsin, this day to do him honor, and extend to Doctor Birge warmest congratulations on his birthday and express the sincere hope that his career of active research and inspirational leadership in the fields of limnology, fishery biology, and conservation will continue for many years.

BE IT FURTHER RESOLVED: That the Secretary of the Society inform Doctor Birge of this action by telegram.

(Upon motion, duly seconded, the resolution was adopted by a unanimous rising vote.)

Prior to the close of the meeting, the President received the following telegram:

"I send my heartiest thanks to the American Fisheries Society and its members for their cordial greetings. They bring to me many happy memories of the Society and of the friendship of its members.

(Signed) E. A. BIRGE."

THE PRESIDENT: A few years ago Doctor Wilfred Rushton, of London, England, was present at one of our meetings. He sends the following telegram, addressed to the President of the Society:

"Doctor Rushton, London, England, sends greetings and good wishes to members and friends."

Apparently he enjoyed his visit with us.

MR. GORDON: May I supplement that by stating that your Secretary a short time ago received an interesting letter in longhand from Doctor Rushton, in which he referred to his visit with us in Grand Rapids, Michigan. He said he hoped soon again to be able to come back and attend one of our meetings.

COMMITTEE ON NOMINATIONS

DR. H. J. DEASON: Mr. President, your Committee on Nominations proposes the following officers for the Society to serve during the ensuing year:

Officers

President, James Brown, Kentucky.
First Vice-President, John Van Oosten, Michigan.
Second Vice-President, Joe Hogan, Arkansas.
Secretary-Treasurer, R. P. Hunter, Connecticut.
Librarian, Kenneth E. Cobb, Connecticut.

Vice-Presidents of Divisions

Fish Culture, John Gottschalk, Indiana.
Aquatic Biology and Physics, Wm. C. Herrington, Massachusetts.
Commercial Fishing, B. M. Brennan, Washington.
Protection and Legislation, Arthur Clark, Missouri.
Angling, James A. Rodd, Ottawa, Canada.

Committee on International Relations

Paul R. Needham, California, *Chairman*.
William C. Adams, New York.
A. G. Huntsman, Ontario.
Charles E. Jackson, Washington, D. C.
A. L. Pritchard, British Columbia.
Will Tucker, Texas.
E. L. Wickliff, Ohio.

Committee on State and National Relations

M. C. James, Washington, D. C., *Chairman.*
T. L. Langlois, Ohio.
C. O. Hayford, New Jersey.
D. N. Graves, Arkansas.
F. J. Foster, Washington.

Committee on Common and Scientific Names of Fishes

Walter H. Chute, Illinois, *Chairman.*
W. A. Clemens, British Columbia.
John R. Dymond, Ontario
Samuel F. Hildebrand, Washington, D. C.
Carl L. Hubbs, Michigan.
George S. Myers, California.
Leonard P. Shultz, Washington, D. C.

I move, Mr. President, the adoption of the report and the election of the officers named.

THE PRESIDENT: You have heard the report of your Nominating Committee and the motion for its adoption. Are there any further nominations? There being none, do I hear a second to the motion for adoption?

MR. GORDON: I will second the motion.

(The officers named were elected by a unanimous rising vote.)

THE RETIRING PRESIDENT: I will ask Mr. Markus and Mr. Hunter to escort the newly-elected President to the Chair.

(The President-elect was conducted to the rostrum.)

THE PRESIDENT-ELECT: Members of the Society, I deeply appreciate the honor you have conferred upon me in electing me as your President. I shall sincerely try to carry out the wishes of this organization in the coming year, and will make every effort to live up to the record of the former President in preparing for the 1941 meeting. I hope you will all feel free to call upon me at any time in connection with the work of the Society. I earnestly solicit your cooperation during the ensuing year. I thank you all very much.

MR. GORDON: I do not know of any other business, but before the meeting adjourns I should like to say a word in regard to the splendid manner in which we have been taken care of by the local committee. The arrangements for the program and the banquet and the meetings in this room have been so thorough that everything has worked smoothly; nothing was forgotten. I should like also to commend the management of the hotel; they were right on the job every minute—I have never worked in a hotel where the management was so cooperative. Believe me, the hotel management in St. Louis next year had better be on its toes.

THE PRESIDENT-ELECT: I concur in that. If there is no further business, I declare this meeting now adjourned, and we will look forward to seeing you all next year.

(The meeting adjourned.)

In Memoriam

John F. Bass, Jr., Chicago, Illinois

E. V. Cassell, Mt. Shasta, California

W. B. Cleveland, Burton, Ohio

Zane Grey, Altadena, California

Louis Horst, Sunderland, Massachusetts

Wilton Lloyd-Smith, New York, New York

Robert H. Stobie, Concord, New Hampshire

John E. Widner, Newtown, Ohio

PART II
PAPERS AND DISCUSSIONS

SALMON SALVAGE PROBLEMS IN RELATION TO SHASTA DAM, CALIFORNIA, AND NOTES ON THE BIOLOGY OF THE SACRAMENTO RIVER SALMON

PAUL R. NEEDHAM AND OSGOOD R. SMITH
U. S. Department of the Interior, Fish and Wildlife Service
Stanford University, California
AND
HARRY A. HANSON
U. S. Department of the Interior, Bureau of Reclamation
Redding, California

ABSTRACT

Studies of the chinook salmon runs which will be blocked by Shasta Dam on the Sacramento River, California, indicate that a total annual run of about 27,000 fish will be blocked sometime in 1942. There are two relatively distinct spawning runs, one in the spring and one in the fall. The number of eggs per female is calculated to be nearly 7,000. There are also two distinct downstream migrations, one in the spring and one in the fall. Most of the young salmon go to sea during their first spring.

It is not considered practicable to install fish ladders over Shasta Dam because of the height of the structure and because young downstream migrants could not pass it safely. Therefore, consideration is being given to salvage plans similar to those used for the salmon runs blocked by Grand Coulee Dam in the upper Columbia River. All tributaries of the Sacramento River below Shasta Dam have been examined as to their suitability for transfer of the run now passing Redding. Of 17 drainages examined, 9 are dry in their lower reaches during part of the year and 7 have dry stretches during periods of salmon migration. Only 2 streams, Battle and Deer Creeks, were found below Shasta Dam which have salvage possibilities.

Not a single effective fish screen was found in the 19 drainages investigated and most fish ladders seen were inoperable because of lack of water.

Copper pollution in the Sacramento River above Redding from abandoned mines may become lethal to trout and salmon unless corrective measures are undertaken.

In the salvage plan recommended by the Board of Consultants it is proposed that three rack barriers be constructed across the Sacramento River between Redding and the mouth of Battle Creek. After river temperatures had dropped below 60° F. in the fall, salmon would be stopped on the expectation that they would spawn naturally between the racks. Because of high water temperatures in the main Sacramento, the spring run and the early part of the fall run would be transferred by trucks to Battle and to Deer Creeks. A hatchery having a capacity of about sixty million eggs is proposed for construction on Battle Creek in connection with this plan. A fish collecting system, including traps and lifts will have to be provided at one of the barriers. Tank trucks will be required for transfer of the fish to Battle and Deer Creeks.

INTRODUCTION

In July, 1938, a biological investigation was started in the upper Sacramento Valley, California, in order to determine the size and composition of the salmon runs in that river and to determine the

best means of preserving runs which soon will be cut off from their spawning grounds by the construction of Shasta Dam. The survey was financed by the Bureau of Reclamation and was supervised by the Fish and Wildlife Service, both of the U. S. Department of the Interior. The California Division of Fish and Game cooperated in many ways, especially in the study of pollution problems and by supplying data from their own investigations in the lower Sacramento River and in the Pacific Ocean. A preliminary report upon the findings and recommendations was submitted to the officials of interested agencies on April 6, 1940.[1] The investigation is still being carried on to gather additional facts and aid in the development of final salmon salvage plans.

The present paper is a condensation of parts of the report mentioned above, with the addition of some material brought out by the investigation conducted since the preparation of that report. Several possible salvage plans have been suggested in the report but only one, that recommended by the Board of Consultants appointed by the Bureau of Reclamation, is discussed in this paper. The Board of Consultants consisted of an engineer, an economist, and a fishery biologist: Professor W. F. Durand, Stanford University; Professor R. D. Calkins, University of California; and Professor Willis H. Rich, Stanford University.

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Much help has also been given by Mr. Harlan B. Holmes, In Charge, Hydraulics Section, Fish and Wildlife Service, who directed the work in connection with design of the salvage facilities, and Mr. Fred J. Foster, Director, Western Division of Fish Culture, for the same agency, who directed the study of the fish-cultural aspects of the problem.

Messrs. N. B. Scofield, G. H. Clark, Paul Shaw, S. Ross Hatton, and other members of the California Division of Fish and Game staff have cooperated in supplying much needed data.

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The Salmon Salvage Problem

The Sacramento River salmon fishery was once a major industry in California. In 1882, 21 canneries were in operation and 12,000,000

[1]Hanson, Harry, Osgood R. Smith, and Paul R. Needham. 1940. An investigation of fish-salvage problems in relation to Shasta Dam. U. S. Bur. Fish., Special Scientific Report 10, pp. 1-200. (Mimeographed.)

pounds of fish were taken from the river. The resource has been reduced to but a small fraction of its former value but commercial fishermen still produce about one million pounds of salmon a year.

The chinook or quinnat salmon (*Oncorhynchus tschawytscha*) in California has fought a long but losing struggle against the activities of man. Dam after dam has cut off its spawning beds, hundreds of unscreened diversions have destroyed its young on their way to the sea and hordes of fishermen in the river and ocean have taken their toll from the returning runs.

Now Shasta Dam is being constructed on the upper Sacramento River in northern California as the principal feature of the Central Valley Project. It is to be a multiple-purpose dam for navigation improvement, flood control, supplemental irrigation, salinity control in the lower Sacramento Delta region, and electric power generation. Shasta Dam, the second largest in the world, will be approximately 560 feet high. It will cut off all salmon spawning areas above it in the Sacramento, Pit and McCloud Rivers and their tributaries.

Keswick Afterbay Dam will be built 6 miles below Shasta, to regulate flows in the river and generate additional power. Actually, this dam, rather than Shasta, will be the upper limit of the salmon migration.

All the important tributaries above Shasta Dam and below as far as the City of Sacramento were surveyed to determine the amount of spawning area lost and the amount which will be left after completion of the dam, and to determine their suitability for transfer of the runs. Of 17 drainages examined below Shasta Dam, 9 are dry in the lower reaches and 7 have dry stretches during the periods of salmon migrations. Only two tributaries, Battle Creek and Deer Creek, were found to have any salvage possibilities. Of these, Battle Creek could be used only for artificial propagation because of power developments, and Deer Creek is relatively small and fully utilized for irrigation in its lower reaches. The others are too small, dry, or too far from Redding.

Not a single effective fish screen was found in the 19 drainages investigated and most fish ladders were impassable because of lack of water.

In addition to the field survey of the Sacramento Valley, biological studies were carried on to learn the size of run and all possible information on the biology and habits of the Sacramento salmon.

The plan to build a huge dam on the Sacramento River had been in print for at least 7 years (California Division of Water Resources, 1931), but no serious effort was made to investigate the fishery resources affected until construction had already been started. Inasmuch as construction is expected to reach a stage late in 1941 or early 1942 when migratory fish will no longer be able to pass the damsite, barely 3 years have been allowed for field studies, the compilation of a report, the consideration of proposed salvage plans by a Board of

Consultants and the actual construction of some of the salmon salvage facilities. It has been necessary to work against time, as has too often been the case when dams have imperiled migratory fishes. To make matters worse for salmon, Shasta Dam is only one unit, albeit a tremendous one, of a whole series of proposed dams in practically every river in northern California. Among the future dams in these plans is one at Table Mountain in Iron Canyon on the Sacramento River a few miles above Red Bluff, which will form another impassable barrier to the salmon of the main river. It will also be below all the proposed facilities for salvaging the salmon blocked by Shasta Dam.

Only the lower regions of the Sacramento Valley will remain accessible to migratory fish after the completion of Shasta Dam, and the problem of preserving a run of perhaps 27,000 fish in such country presents tremendous difficulties. There are no streams large enough so that all these fish might be transferred to them for natural spawning.

Although it would be possible to get salmon over Shasta Dam so they could go upstream to spawn, the difficulties of getting the young fish down past the dam on their way to the sea are insurmountable. There are three sets of river outlets in the dam and the outlets are 90 feet apart vertically. Whenever the reservoir is below maximum level, all the water will go through these outlets and the penstocks, and thus young salmon would be forced to take one of these routes. Young fish could not survive the sudden release of pressure if they were to go through the river outlets, nor can they be expected to survive the hazardous trip through the turbines.

The maximum water level of Shasta Reservoir will be 495 feet above the mean river surface, and there will be a fluctuation of 237 feet. A collecting device, capable of screening the very small young salmon out of the river outlets and penstocks, would have to be adapted to this fluctuation and it is doubtful that an apparatus could be constructed which would operate successfully and not hinder the flow of water. Therefore it has been necessary to consider means of salvaging the salmon by transfer to other streams or by hatchery operations rather than passing them over the dam.

Size and Time of Upstream Migrations

Two well-marked annual chinook salmon runs pass up the Sacramento River, one in the spring and one in the fall (Fig. 1). Salmon were counted as they passed through the fishway in the Anderson-Cottonwood Irrigation Company Dam at Redding, California, 13 miles downstream from the site of Shasta Dam. This dam is a demountable structure which is removed after the irrigating season, so counts could not be made throughout the year. The California Division of Fish and Game counted 7,781 in 1937 from August 7 to October 15. The Bureau of Reclamation counted 13,885 chinook salmon

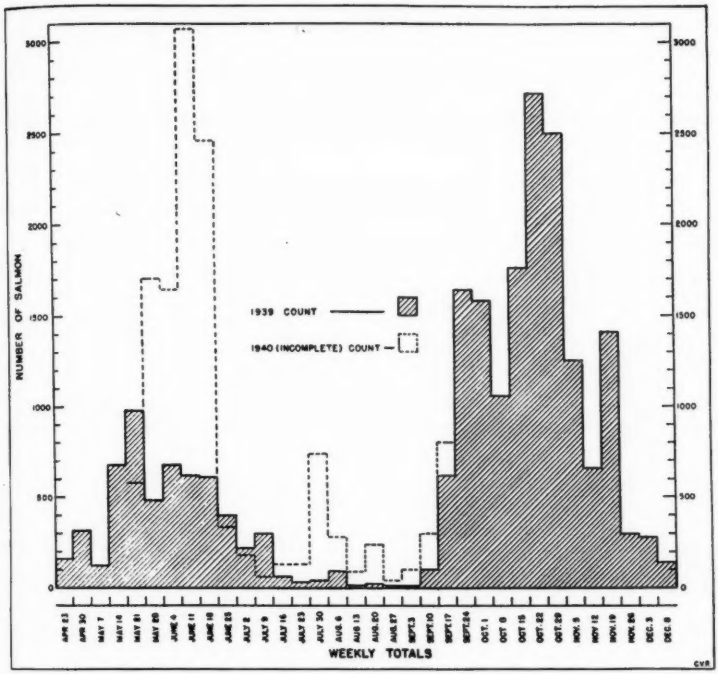

Figure 1.—Salmon counts at Redding by weekly totals; 1939 count complete; 1940 fall count incomplete.

from September 3 to October 26, 1938, inclusive, and in 1939, the actual count was 21,894. Table 1 shows the distribution of these counts, as well as the two peaks composing the spring and fall runs. September 1 was set as the end of the "spring run," though actually the upstream movement was continuous during the period of the counts. There is also some evidence, discussed later, that the spawning migration continues through the winter, thus forming a continuous, year-long upstream movement.

Allowing for the unknown number of fish coming upstream in the winter and a small safety factor, 27,000 salmon a year was assumed to be the probable total number of fish that will have to be saved. That this is not an overestimate seems to be clearly shown by the 1940 counts. Between May 16 and August 11, 1940, 11,508 salmon were counted past Redding. If the 1940 fall run is no smaller than it was

in 1939, the actual count, not including the winter fish, will be around 27,000. It may be necessary to place our estimates even higher if present plans are going to take care of the run. If the fall run also increases in size, the salvage facilities as already planned may not be large enough to handle the run. The small size of the springs and streams available will not permit a large increase in the salvage facilities.[2]

Table 1.—Weekly Counts of Salmon at Anderson-Cottonwood Dam, Redding, 1937-1940

Week ending	1940	1939	1938	1937
April 23	.....	164	.....	.....
April 30	.....	224	.....	.....
May 7	.....	119	.....	.....
May 14	.....	681	.....	.....
May 21	585	983	.....	.....
May 28	1,700	488	.....	.....
June 4	1,645	697	.....	.....
June 11	3,075	633	.....	.....
June 18	2,456	623	.....	.....
June 25	344	395	.....	.....
July 2	160	219	.....	.....
July 9	62	297	.....	.....
July 16	129	56	.....	.....
July 23	129	28	.....	.....
July 30	745	39	.....	.....
August 6	289	95	.....	.....
August 13	82	7	.....	13
August 20	238	19	.....	7
August 27	38	15	.....	2
September 3	108	6	6 (c)	16
September 10	315	96	21	35
September 17	806	625	38	114
September 24	.....	1,641	64	175
October 1	.....	1,591	168	967
October 8	.....	1,077	912	1,172
October 15	.....	1,754	1,394	5,280
October 22	.....	2,731	2,054	..... (f)
October 29	.....	2,497	8,174	.....
November 5	.....	1,258	1,054 (d)	.....
November 12	.....	680	..... (e)	.....
November 19	.....	1,418	.....	.....
November 26	.....	302 (b)	.....	.....
December 3	.....	286	.....	.....
December 8	.....	150	.....	.....
TOTALS	12,906	21,894	13,885	7,781

(a) and (b) Total for 6 days.
(c) Total for 1 day.
(d) Total for 5 days.
(e) 5,500 additional fish estimated as passing dam site.
(f) 10,900 fish estimated October 16 to October 23.

The peak of the spring run in 1939 occurred on May 11, and in 1940 on June 10. On the former date 308, and on the latter, 640, fish were counted through the ladder at Redding. The peak of the fall run in 1939 occurred on October 24 when 785 were recorded. The peak in 1938, which gave a higher daily count, cannot be accepted as significant because this influx of salmon immediately followed an improvement of current conditions at the weir.

The percentage of the run by hours throughout the day indicates

[2]The complete count from May 16 to Oct. 31, 1940, was 40,245 salmon. The count was stopped during or before the peak of the fall run and there is evidence that the total run was about 60,000 salmon.

for spring-run fish, a morning peak between 7 and 8 a.m. and two smaller, secondary peaks between 3 and 4 p.m. and 7 and 8 p.m. For fall-run fish, the peak came about an hour later, between 8 and 9 a.m., gradually falling off until noon. A second peak then came between 3 and 4 p.m., when shadows started to fall across the ladder, finally dropping off in the evening. Sample counts made at night indicated that very few fish attempted to pass through the fishway after dark.

Other Fish

In addition to the salmon, a few other kinds of fish were counted through the fishway. Their numbers are summarized in Table 2.

Table 2.—Summary of scrap fish passing Redding, 1939

Season	Sacramento sucker	Sacramento pike[1]	Carp	Shad	Steelhead trout	Brown trout
Spring (Apr. 17- Sept. 1)	2,525	55	4	11	36	0
Fall (Sept. 1- Dec. 8)	0	0	0	0	82	114

[1]Probably includes two species of large cyprinids, *Ptychocheilus grandis* and *Mylopharodon conocephalus*.

The number of steelhead trout (*Salmo irideus*) counted was small. From April 17 to December 8, 1939, only 118 steelhead trout passed through the fish ladder. Some must have gone through earlier, but still the steelhead run is apparently not large enough to attract anglers in any numbers.

Length and Weight of Upstream Migrants

During the fall run of 1938, from September 29 to October 15, a sample of 874 salmon were weighed and measured. Fish were captured with a large dip net in the fish ladder below the weir, and it is believed they constitute a random sample of the run. Total lengths, from the snout to the fork of the tail, were measured and the fish were weighed in a wet sack on a steel-yard. A scale sample was taken from each fish before it was released above the fish ladder. Weights varied from 3.75 to 50 pounds, and lengths from 42 to 113 centimeters. The average weight of 804 fall-run fish weighed in the manner described above was 18.8 pounds. This figure is roughly 1 pound in excess of the true weight, because of the weight of the wet sack. About 30 per cent were grilse. This percentage was calculated from the number of male fish less than 71.5 centimeters in length. This arbitrary length was decided upon as a basis of separation because it was the low point between the two peaks of the length frequency curve for the sample (Fig. 2). A sample of 142 fish of the spring run and 150 from the fall run of 1939 was secured in the same manner as in 1938. The spring run was sampled on various days between May 11 and June 3, 1939, and the fall run between October 3 and 20, 1939. The average

weight of 112 fish from the 1939 spring run was 18.1 pounds; of 149 fish from the fall run, 19.4 pounds, including the sack. Lengths varied from 46.5 to 102 centimeters for the spring run, and from 47.5 to 117 centimeters for the fall run.

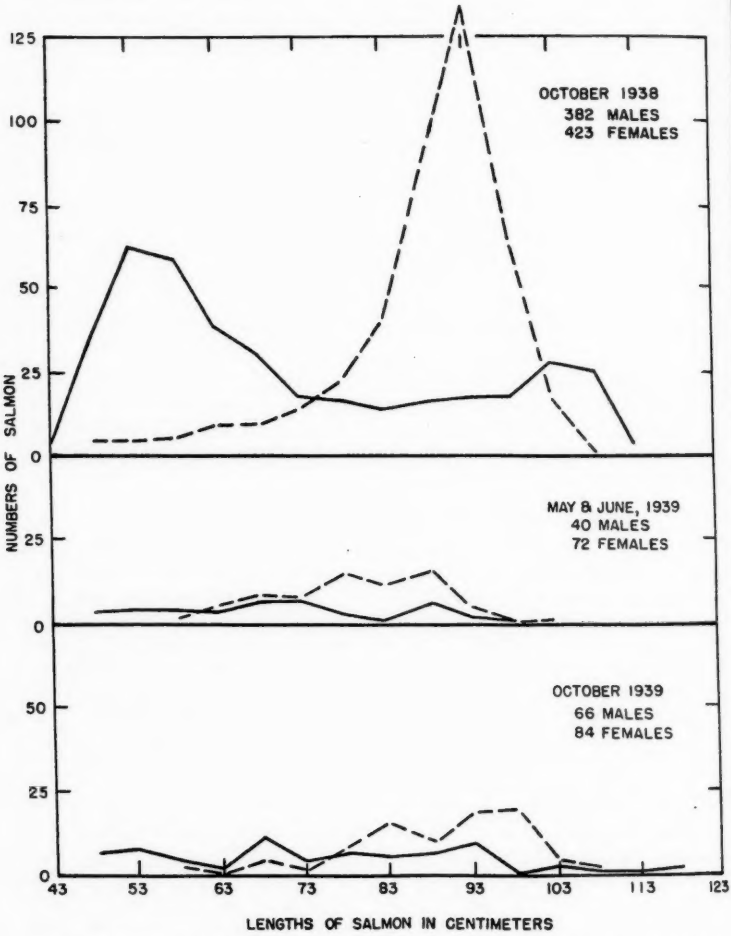

Figure 2.—Length-frequency distribution of male (solid line) and female (broken line) salmon sampled at Redding, 1938-1939.

Sex Ratio

The sex ratio in the sample taken in October 1938 was 382 males to 423 females or approximately 47.5 to 52.5. The ratios of the smaller samples taken in 1939 were 40 males to 72 females for the spring run and 66 males to 84 females for the fall run, but because of the small size of the samples, no significance was attached to this unusual ratio. A male to female ratio of 1:1 appears to be normal, and this was used in planning salvage facilities.

In contrast to the numbers of grilse in the run passing Redding were the amazing number of grilse that occurred in the fall runs of 1939 at the Battle and Mill Creek Hatcheries of the Fish and Wildlife Service. Battle and Mill Creeks join the Sacramento River about 18 and 50 miles, respectively, below Redding.

Of the 14,861 salmon handled at Battle Creek 847 females were spawned between October 30 and December 4, 332 females were found dead in the holding pond after having spawned naturally, and 12,695 grilse were counted. Grilse constituted over 85 per cent of this run.

The Mill Creek run showed an even greater disproportion in the numbers of male to female fish. Of 21,402 salmon seined and counted at the holding pond, only 184 were females. The hatchery superintendent estimated that there were about the same number of large males as females, and that the balance, or about 98 per cent, were grilse. There is no information at hand to account for the large proportion of grilse in these two small streams. Such an occurrence sometimes precedes an increase in the size of the run, but not always.

Fecundity of Sacramento Salmon

The average number of eggs produced by Sacramento salmon was computed from 57 samples. Twelve were taken from the Sacramento River at Redding between May 15 and July 15, and 45 from Battle Creek between June 14 and September 10, 1939.

Two methods were used in computing the number of eggs per fish: First, the total weight of the eggs in the ovary was multiplied by the number of eggs per gram as determined by weighing the counted sample, and second, the liquid displacement of the total number of eggs was multiplied by the number of eggs per cubic centimeter. Three samples were counted to check the two methods of computing. Both methods were found to be reasonably accurate, neither showing any large or consistent deviation from the actual count.

In Table 3 the actual counts and computed numbers are compared with the three check samples of the counts made in this study. The mean of the two methods has been accepted as nearest the true value since it was believed that it would tend to reduce the average percentage of error.

Table 3.—Comparison of two methods of counting salmon eggs

Actual count (One ovary)[1]	Computed by volume	Percentage error by volume	Computed by weight	Percentage error by weight	Mean	Percentage error of mean
2,543	2,723	7.0	2,574	1.2	2,648	3.7
3,452	3,500	1.3	3,387	1.8	3,445	0.2
2,783	2,771	0.4	2,720	2.1	2,745	1.3

[1]These checks were made on Battle Creek samples, in which only one ovary was preserved.

Both ovaries were preserved in the Sacramento River samples, but in the Battle Creek samples only one ovary was preserved. The total number of eggs in the Battle Creek lots was computed by multiplying the original calculations by 2. The average of 6,253 eggs per fish for Battle Creek derived from these calculations is slightly less than the 29-year average of 6,534 from the Battle Creek Hatchery records, but falls well within the extremes of yearly averages for that station.

In addition to these counts, direct counts were made in 1938 of eggs from the right ovary of three immature salmon from Battle Creek. The counts, doubled to allow for the eggs in the left ovary, were 7,810, 9,570, and 6,680. The average was 8,020.

The average number of eggs per fish derived from all the 57 samples taken in 1939 was 6,404. The average of 12 samples from the Sacramento River was 6,970, and the 45 samples from Battle Creek averaged 6,253. The Battle Creek counts varied from 4,287 to 11,223, a range of 6,936. The Sacramento River samples were more homogeneous, with extremes of 4,006 and 8,846, a difference of 4,840.

McGregor (1923), in his study of 50 samples, derived a mean of 7,454 eggs per fish, with extremes of 4,795 and 11,012, a range of 6,217. These figures represent the number of eggs in salmon at Suisun, where the fish have just begun their migration up the river. Estimates of fecundity derived from studies of ripe fish and fish-hatchery records must take into consideration the loss of eggs by spawning or other causes.

Table 4.—Egg counts of Sacramento salmon

Observer	Date	Method	Locality	Average per fish
McGregor	1923	Comput. from sample (55 fish)	Suisun	7,454
Hatchery rec.	1909-1938	Calculated from records	Battle Creek Hatchery	6,534
Hatchery rec.	1912-1939	Calculated from records	Mill Creek Hatchery	6,477
Survey party	1938	Comput. from sample (3 fish)	Battle Creek	8,020
Survey party	1939	Comput. from sample (45 fish)	Battle Creek	6,253
Survey party	1939	Comput. from sample (12 fish)	Sacramento R. at Redding	6,970

All the samples available for the survey study were taken from dead fish, some of which were ripe and may have begun to spawn. This might account for the slightly higher average given by McGregor, though both sets of counts showed such extreme variability that the difference between them probably has no real significance. From this

data it is evident that the average yield of eggs per female Sacramento salmon must be nearly 7,000, and this figure has been used in estimating the possible number of eggs to be handled in hatcheries.

There is no evidence from the figures available of any racial differentiation so far as the numbers of eggs are concerned in the two tributaries, Battle and Mill Creeks, and the main river runs of fish, such as has been demonstrated by McGregor (1923) for Klamath and Sacramento River salmon.

Based on a 1:1 ratio of females to males, and a rounded-off estimate of 7,000 eggs per female, a total of 76,640,000 eggs can be expected from the run of 21,894 salmon which passed the Anderson-Cottonwood Irrigation Company Dam at Redding during the spring and fall of 1939. If the total run was 27,000 fish (13,500 females), on the same basis, a potential egg production of 94,500,000 might be expected.

Seaward Migrations

A number of workers, including Scofield (1900), Rutter (1903), Rich (1920), and Clark (1929), have shown that the bulk of young fish start their downstream migration in the spring soon after emerging from the gravel and starting to feed. Rutter (1903) captured seaward migrants from January 6 to April 25, 1899, at Ball's Ferry, near the mouth of Battle Creek. He found that the height of the migration occurred between the first and fifteenth of February.

Fyke net catches made by the staff of the California Division of Fish and Game at Hood Station below the City of Sacramento in 1939 showed that the peak of the migration occurred between March 20 and 25, and during the 1939-1940 migration, young salmon fry were collected from December 14, 1939, to May 28, 1940. The peak of this migration occurred about the last of February. It is interesting to note that the spring downstream migration starts as early as December 10 (Hatton, 1940).

Seaward migrant fish from the run of 1938 travelled downstream past the Anderson-Cottonwood Irrigation District Dam at Redding from April 18 to June 8, 1939. No attempt was made to collect fish before April 18, but from the investigations of Rutter and others it may be assumed that a large part of the run had already passed downstream.

Observations made in 1939 at Redding showed that there was a seaward migration of young fish in the fall as well as in the spring. Young fish 3 to 4 inches long were seen going over the crest of the dam and down the fish ladder at Redding in large numbers from September 13 to November 15, with a peak about September 20 or 25. None of the fish that passed over the dam was collected, but young salmon 3 to 5 inches long were caught on flies during July at Baird after the spring migration. The fish probably were staying in the

river over the summer and probably would move downstream at the approximate age of 1 year. The discovery of a fall migration, herein reported for the first time, is an interesting confirmation of the statement made by Rich (1920, p. 70) from evidence of scale studies, that "it is probable that there is another period of seaward migration during the late autumn."

In an appendix to the unpublished and confidential "Report of the Board of Consultants on the Fish Problems of the Upper Sacramento River" (1940),[3] it is stated "that approximately 90 per cent of the young quinnat[4] salmon in the Sacramento leave fresh water for the ocean in the early spring following the fall in which eggs are deposited; that the height of the migration past the region of Battle Creek is during the period from the middle of January to the middle of March . . . . and that the majority of the young salmon enter the ocean not much later than the first of June." On the basis of early seaward migration, the Board of Consultants recommended that young salmon artificially reared in connection with the salvage program, should be planted "late in the winter or early in the spring so that they may make the seaward migration at the normal time."

Young salmon fry captured in the Sacramento River and in various tributaries by the survey party during April, May and June, 1939, had an average length of 41.26 millimeters (1.62 inches). Rutter found in 1899 that the seaward migrants passing in the vicinity of Battle Creek had an average length of 1.5 inches.

The fall downstream migrants, which remain in for a period of about a year average about 4 inches (100 millimeters). Dr. Rich in the Board's report considered that these fish are from both the spring and the fall run.

One observation of special interest made by the survey was that chinook salmon were seen spawning in the McCloud River during May and June, 1939. On May 26, 25 adult salmon were seen on nests, and a spent female was found with only 4 mature eggs in the body cavity. A number of fish had worn caudal fins, abrasions, bruises on the body, and the fungus growths which usually are correlated with spawning activities. On June 23, 1939, eggs were recovered from two nests, and on June 27 a sample was secured from a third nest. On August 5, eyed eggs and alevins were taken from two nests, and on September 29 several young salmon were seined from the McCloud River at Big Springs.

This is the first time chinook salmon have been reported to spawn in the spring and points to the possible existence of a third or winter run of fish in the Sacramento. It was largely this evidence which led us to believe that allowance must be made for winter run salmon in any salvage plans and to add a sizable "safety factor" to the actual counts of salmon past Redding.

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[3]Memorandum to the Commissioner, Bureau of Reclamation, June 21, 1940.
[4]Also known as king, chinook, and tyee salmon.

The Salmon Salvage Plan

The plan adopted is known as the Sacramento River natural spawning plan. It provides for transferring the spring run to a hatchery and for holding the fall run salmon in areas of the Sacramento River below Keswick until they spawn naturally. This plan has been recommended by the Board of Consultants as the most feasible from the economic and biological points of view. Under this plan, most of the fall run would be held in the main river, where they would be expected to spawn naturally. The early fall run, which arrives while the water is still warm, would be taken to a new hatchery on Battle Creek. Since water temperatures at present are too high for holding the spring run in the main river, the entire spring run would be trapped and transferred. Some would be taken to holding ponds on Battle Creek and some probably to Deer Creek for natural spawning.

According to a resurvey of the main Sacramento River made in the summer of 1940, there is space for about 11,000 salmon nests in the main river between the site of the proposed Keswick Dam and the mouth of Battle Creek. This estimate was made by mapping with a plane table the possible spawning areas, and allowing 50 or 100 square feet per nest, depending upon the type of bottom. This estimated spawning accommodation is a decided reduction from the original estimate of 20,000, based on pacing, but it still provides room for a run of about 22,000 fall run salmon. To take advantage of this potential spawning area, three or more racks would be installed in the main river and a definite number of salmon permitted in each area according to the estimated capacity of the area.

The proposed hatchery on Battle Creek will have a capacity of approximately 57,600,000 eggs and will be similar in size to the one at Leavenworth, Washington. This establishment will take care of the transferred fish and replace the existing Battle Creek Hatchery. A series of holding ponds are proposed at Darrah Springs, on upper Battle Creek, where some of the spring run fish can be held for ripening in spring water at 56° F. In order to transfer the spring run, traps will be constructed in the afterbay of Keswick Dam in the main river some 6 miles below Shasta Dam. Another set of traps may be built in the lower rack near the mouth of Battle Creek to reduce the distance that the fish will have to be hauled. A fleet of about seven tank trucks will be needed to transport the fish.

There are three problems which must be dealt with if this salvage plan is to be successful: Pollution from copper mines, river temperatures, and flood conditions. Preliminary studies of mine pollution in the reservoir area by Mr. Paul Shaw, California Division of Fish and Game, which formed an appendix to the report mentioned in Footnote 1, indicate that concentrations of dissolved copper in the river at Spring Creek, immediately above the Keswick damsite, were near the lethal limit for trout and possibly small salmon for most of

the period from November, 1939, to February, 1940, and above the lethal limit for several days during that period. While there is no way to determine the possible losses caused by dissolved copper to naturally spawned eggs and alevins in the main river, it is reasonable to assume that it certainly has no beneficial effect. Therefore no plan in which salmon would be concentrated for natural spawning immediately below the source of this pollution should be considered until measures are taken to reduce the concentration of copper.

Temperatures above 60° F. have been found to cause high mortalities among salmon being artificially held for ripening. Since temperatures in the main river are sometimes above 60° F. until late in September, the spring run and part of the fall run would have to be trapped and handled elsewhere. Most of the big floods in the Sacramento River come after the fall spawning season, when there are not so many salmon coming upstream, but floods occur often enough in the fall so that the racks would have to be built to withstand high water conditions. Records from the Red Bluff gauging station show that in 43 years there were 18 times when flows were over 10,000 cubic feet per second before or about the middle of November; 10 floods occurred with peaks of over 30,000 cubic feet per second; and there were 2 floods of over 100,000 cubic feet per second. The spawning period lasts until December, and therefore the racks might have to withstand flash floods characteristic of the upper Sacramento River Basin.

The most serious disadvantage of this plan is the uncertainty of its success. Behaviour of fish when held behind racks in the main river cannot be predicted. They have been known to drop back and spawn below obstructions, but there is no assurance that a run can be successfully maintained by this means. Furthermore, observations of fish held between racks show that the fish tend to concentrate toward the upper end of the holding areas rather than to distribute themselves evenly over them, and they almost invariably suffer from bruises from fighting the racks. If the salmon fall back downstream to suitable spawning areas, there is no positive proof that there will be room for them. Estimates of spawning areas are very rough at best, and this is especially true in a river as large as the Sacramento. We know that salmon spawn in the area, but just how many will crowd into it cannot be foretold. The estimates presupposed that the fish will crowd together rather closely in all the suitable areas, yet we have no proof that the chinook salmon will do this. Alaska red salmon may do it, but one cannot generalize between species. Also the speed of current and the size of gravel required by nesting salmon must be estimated, and all these things introduce sources of error which might halve or double the spawning area estimates.

There are also many unknown factors in hatchery propagation of salmon. It has been demonstrated that a small run of salmon can be maintained artificially but to do so with a large run of commercial proportions may prove more difficult. The usually sudden transfer

of young fry from hatchery conditions to wild conditions may cause heavy losses aside from predation and there will be the ever-present dangers of disease, floods, and other accidents. Even though hatchery mortality may be lower than mortality under natural conditions, the "post-hatchery" mortality may be much higher.

A further disadvantage is the threat of the Table Mountain or Iron Canyon Dam. This dam would flood out all spawning areas between it and Redding. In short, the future of the Sacramento salmon runs does not look bright.

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RELATION OF THE FISHERY ADVISORY COMMITTEE TO THE COMMERCIAL AND SPORT FISHERIES

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The Fishery Advisory Committee was organized in 1935 by former Secretary of Commerce Daniel C. Roper in an attempt to provide a greater measure of aid to the fishery industries.[1] Its first meeting was held in Washington on May 6 of that year. Since that time eight meetings have been held, the last one occurring on January 31 and February 1, 1940, in the Secretary's conference room of the new Department of the Interior Building.

The Committee as now constituted has 32 members, who are divided into subcommittees representing the following seven areas: the Great Lakes and Inland Waterways Region, the North Atlantic Region, the Middle Atlantic Region, the South Atlantic Region, the Gulf Region, the North Pacific Region, and the South Pacific Region. Membership includes representatives interested in commercial and sport fishing who are associated with State conservation departments; a shellfish trade association; a university; a planning council; the legal, banking, and publishing professions; and fish production, processing, and marketing.

It is now the official purpose of this committee to furnish advice to the Fish and Wildlife Service through recommendations presented to the Secretary of the Interior. The group is interested in furthering the progress that is being made in fishery resource management and fish production, processing, handling, and merchandising. It attempts to guide the Federal Government in interpreting fishery problems and working with the fisheries, and tries to establish and maintain a wholehearted spirit of cooperation between the Federal fishery authorities and the fishery industries. Representative informed portions of the public are in a position to contribute constructive advice to government administration. The provision of such advice on fishery matters tends to insure that government fishery work functions along the lines of maximum benefit to the public.

The Committee's recommendations are formulated in a genuinely solicitous attitude and have been received in a spirit of fullest cooperation by the Government. Perhaps the strongest indication of the public-spiritedness of the Committee's deliberations is the cooperative

[1]With the transfer of the Bureau of Fisheries from the Department of Commerce to the Department of the Interior on June 30, 1939, the Fishery Advisory Committee was continued with the expressed wishes of Secretary of the Interior Harold L. Ickes. The Committee also was continued on the same basis at the time of the abolition of the Bureau of Fisheries and Bureau of Biological Survey on June 30, 1940, and the simultaneous creation of the Fish and Wildlife Service to carry on the functions of the two former agencies under a single administration.

manner in which the members personally interested in the commercial use of the fishery resources and those who are sport fishermen have worked together. The recognition of the need for working together has been reflected in cooperative relations of commercial and sport fishing interests outside the Committee. Its influence has been apparent in the Great Lakes region where cooperation between commercial and sport fishermen has contributed recently to some improvement in conservation legislation.

The Committee has also voiced opinions representative of the commercial and sport fishery interests separately upon occasion. Especially in the case of the commercial fisheries has this been of importance as no other public voice representative of America's combined commercial fishery interests has been existent in recent years.

The fishery resources constitute an important asset to our country. The value of commercial fish and shellfish transactions has been estimated to be greater than one billion dollars annually. This figure includes all financial transactions involved in selling and handling fishery products from point of production until their ultimate consumption. The commercial fishery activities support in addition an inestimable amount of employment and investment in fishing gear manufacture, boat building, processing plant construction, and production of raw materials in agriculture, mining, lumbering, and other basic industries. Also indirectly supported is considerable activity in advertising, transportation, finance, insurance, brokerage, and foreign exchange.

The importance of the fishery resources cannot be mentioned in value of the commercial fisheries alone, however, for they are the basis of sport fishing activity involving almost one-tenth of our population and extending to most of the water surfaces, large or small, throughout the length and breadth of the land. Sport fishing trips cost American sportsmen hundreds of millions of dollars annually and an estimated 25 million dollars is spent on sport fishing tackle each year. The recreation supported by the resources in this way is of immense importance in national health and psychology. In this connection, the contributions of the commercial fisheries to the national health are also of intangible but important consideration, for the food elements provided are desirable in balanced diets and indispensible in the treatment of many deficiency disorders.

The immense economic value of commercial and sport fishing and their contributions to our health and recreation make it obvious that the fullest measure of cooperation must be maintained continuously in the operating of commercial fishery interests, sport fishermen, and the various governmental conservation agencies. The operation of such a relationship as exists between the Fishery Advisory Committee and the Federal fishery authorities goes a long way toward providing that cooperation.

RESEARCH IN FOOD TECHNOLOGY IN THE DEVELOPMENT OF OUR FISHERY RESOURCES[1]

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Technology as it applies to the fishery industries is to an important extent "food technology." The latter term is adequately described in the preamble to the constitution of the newly founded Institute of Food Technology, which states "Food technology is defined as the application to food handling of a group of related sciences and engineering arts. These sciences which underlie the technical problems of the handling of foods include chemistry, physics, biology, and microbiology. In food technology, these are essential to the functioning of a food manufacturing plant. Knowledge of food technology enables its possessor to develop new products and processes, to select proper raw materials, to understand and control the fundamental changes of composition and of physical condition of foodstuffs in their industrial processing, the technical problems of distribution and the sanitation and safety of foods."

The most important use made of fishery products is their consumption as human or animal food. For this use, they are supplied in the fresh state and preserved in many ways such as canned, dried, salted, and frozen. It is in preserving fishery products that food technology has been of greatest value, although it has also been of material assistance in improving methods of catching, handling, and transporting fish.

In ancient times the only methods of preserving fish were drying, smoking, and salting. It was not until 1810 that Nicholas Appert, a Frenchman, discovered the art and science of canning foods. The Underwood Company of Boston canned a small amount of Atlantic salmon in glass jars shortly after 1820. Moderate quantities of Pacific salmon were canned shortly after the War between the States. The use of canning processes was thereafter enlarged until today there are more than 50 kinds of marine products preserved in this way. Smoking and salting methods have also been increasingly used as scientific principles have been applied to the processes.

The use of canning, smoking, and salting methods has been of rapidly increasing importance in the preservation of fishery products for food, but the greatest progress in preserving has occurred in the field of refrigeration and freezing. This development is relatively modern and one which shows great promise for enlargement in the future.

The utilization of species not desired for food and of wastes for fertilizer, oils, leather, and animal feeds is also a technological de-

[1]Contribution No. 383, Massachusetts Agricultural Experiment Station.

velopment to which the fishery industries may point with pardonable pride.

American vision, ingenuity, and technological skill have been instrumental in giving our fishery industries a preeminent status in food technology. Our only close competitors in this field are the Norwegians and the Japanese. While this position of leadership may be viewed with satisfaction, there are still innumerable problems to be solved, and there are relatively few scientists at work on studies designed to solve these problems. Much more attention is being paid to other phases of food technology. Subsidized food research in the huge U. S. Department of Agriculture with its regional laboratories has its ramifications in every county in every State. There are also fully equipped and manned agricultural experiment stations in every State and Territory. Furthermore, every State pours out annually great sums for agricultural vocational training and research in the universities and colleges. Compared to this vast effort in behalf of agriculture, the fishery industries have been assisted by the comparatively small Fish and Wildlife Service of the U. S. Department of the Interior, with only two laboratories working on technological problems, and by comparatively sporadic and insignificant efforts by a few States, namely, Oregon, California, Washington, Maryland, and Massachusetts. A few of the larger commercial interests have thus been forced to carry on the greater burden of research for the fisheries.

In contrast to the feeble efforts of the United States Government in approaching the problems of the commercial fisheries in food technology, Canada has established several regional laboratories and schools for the study of biological and technological problems. These units are now making excellent progress.

There is not one institution of higher learning in the United States at the present time where collegiate training in fishery technology may be obtained. We have schools of agriculture, mines, textiles, business, and commerce, but no schools of applied fisheries. One might well wonder whether the fishing industry has no problems, whether it lacks a convincing voice in our Federal and State economy, or whether our educators have simply overlooked an opportunity.

It is my opinion that one of the most fertile fields of research lies in the fishery industry. This is a field most likely to yield dividends in new industries, improved products, increased employment, and financial gain. While the quality of the work of the Fish and Wildlife Service, the Canadian fishery experiment stations, and private industry should not be deprecated, it should be recognized that this is still a vast unexplored field for investigation. There is scarcely a single commercial fishery product that does not need study, improvement, and refinement. Our efforts in the past have been too conservative. We have been too much inclined to "let well enough alone." Ours is an age of progress and the fishery industry must continually advance

or lose out in competition with fishery products from other countries, or with agricultural foods.

There is real factual competition between fish products and other protein foods such as meats and meat products, cheese, baked beans, legumes, and cereals. American consumers have so many kinds of attractive and tasty foods available that they are able to select for consumption those foods for which they develop preferences. They can easily find it unnecessary to purchase fish, particularly when fish products are available only in unattractive or inconvenient form. It is then logical that the homemaker substitutes something else for her table. If the fishery industry is to retain or enlarge the markets for its products it must meet an urgent need for technological progress by the prosecution of thorough investigations into subjects such as the chemical composition of fish, the nutritive value of fishery products, the factors affecting decomposition and quality-degeneration, handling methods, preservatives, packaging, and retail marketing methods.

Description of certain technological developments in the crab industry may be used to illustrate how research on practical problems in the fisheries yields dividends in new industries, improved products, increased employment, and financial gain. At least four edible crabs contribute to the commercial crab fisheries of the United States. The four important species are the blue crab of the South Atlantic and Gulf Coasts (*Callinectes sapidus*), the Dungeness crab of the Pacific Northwest and Alaska (*Cancer magister*), and the sand and rock crabs of New England (*Ovalipes ocellatus* and *Cancer irroratus*). In 1938, about 96 million pounds of crabs were taken in the commercial fisheries of the United States. Of this yield, only about 2¼ million pounds were used for canning, the balance being utilized for the production of fresh-cooked crab meat.

The comparative inactivity of our crab canning industry was not due to any lack of market for canned crab. The available market had scarcely been touched. Fresh-cooked crab meat was marketed only in seaboard cities and even in such cities its use was inhibited because many people continued to view all fresh crab meat with suspicion. Because fresh-cooked crab meat has poor keeping qualities, the U. S. Food and Drug Administration has had occasion to make innumerable seizures and condemnations of this so-called "fresh" meat. While crabs taken by American fishermen were confined by circumstances to a small fraction of the American market which would normally use crab meat, foreign producers made lucrative use of our inability to solve the problem. Japan has exported annually between 10 and 12 million pounds of canned crab meat to the United States, and we have paid between 5 and 6 million dollars each year for this product. With a highly lucrative market wanting its products, and with our coastal waters literally teeming with crabs awaiting use, our own crab canning industry remained practically non-existent. Canned crab meat of fair quality was being produced from Pacific Coast crabs, but other

species, including the abundant blue crab, had never been successfully canned. Here, obviously, was a job for food technology.

A positive effort to solve the technical problems which hindered the development of crab canning in the United States was initiated by the author and others several years ago. Several crab producing areas were visited where conferences were held with fishermen and plant operators in an effort to discover the cause of canning failure. It seemed that every person contacted from Eastport, Maine, to Brownsville, Texas, had attempted to can crabs—all without success. Failure was consistently caused by undesirable change in the character of the crab meat during the canning process. The canned product did not at all resemble the attractive and tasty fresh meat. The most outstanding defects were an unsightly blue color and a disagreeable odor and flavor.

After the completion of this survey, careful analyses were made of the several species of crabs, with special attention paid to the mineral, protein, and sulphur content of the flesh. Studies included observation of the action of heat on crab flesh and how this action was influenced by acidity, state of the molt, variations in crabs due to differences in the waters where captured, seasonal variations, and other factors. A series of experimental packs of crab meat in various kinds of containers was made. Entirely new methods of handling crabs and picking out the meat were tried. The effect of many chemical substances on crab meat was studied. During several years of research the answers to the various questions slowly unfolded. In such work, as in all research, there is no rapid or haphazard means of reaching the objectives. Fundamental sciences must be constantly utilized and facts must be established one by one. Keen observation is equally as important as scientific ability, and, similarly, deductive ability is required, for the problems are largely practical problems. Also, the necessary understanding of the objective of the research job must usually be predicated upon a first-hand acquaintance with the practical aspects of fishing, canning, freezing, and other activities.

The research on the canning of crab meat eventually disclosed that the copper in the blood and flesh of crabs was the basis of most of the difficulties of discoloration. A combination of a brief steaming process plus a short dip in an acidified salt brine containing minute amounts of an aluminum salt was developed to effectively and completely control the objectionable discoloration and taste in the canned meat. In 1938, after 6 years of field and laboratory research, the first commercial cannery to use the new process was established in Port Royal, South Carolina. There are now three other canneries licensed to use the process to can crab meat, and other canning firms are negotiating for its use. The process has been successful not only for the blue crab, but, with alterations, for the Pacific Coast and New England crabs as well. The new American canned crab meat has enjoyed a splendid reception from the buying public and it is anticipated

that a sufficient quantity of this meat will be canned in coming years to satisfy all domestic requirements. Thus, technological food research has led to the development of a new industry, thereby producing many benefits to the American public.

The crab canning industry is an example of the effect of food technology applied to practical problems in the use of our fishery resources. Other fishery industries can be similarly benefited by technological progress. The investment of modest sums in laboratories and technological research will yield excellent dividends in many phases of fishery endeavor. Let us not fail to give our Federal, State, and Provincial laboratories and experiment stations the cooperation and financial support they require to carry on this work to the extent justified by its possibilities.

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RATE OF GROWTH OF THE LING, *LOTA LOTA MACULOSA* (LESUEUR)

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ABSTRACT

The otolith method of age determination is shown to be applicable to the ling. A preliminary growth curve, based on 31 specimens, is presented for Lake Opeongo, Algonquin Park, Ontario. A photograph of a broken otolith is submitted.

INTRODUCTION

The ling[1], *Lota lota maculosa* (LeSueur), competes with the lake trout, *Cristivomer namaycush* (Walbaum), for the same food in Lake Opeongo, Algonquin Park. For this reason a study of the distribution, feed habits and rate of growth of the ling is being conducted by the Ontario Fisheries Research Laboratory. The present report on the rate of growth of ling in Lake Opeongo, although based on but 31 specimens taken in 1938, demonstrates that the otolith method of age determination, which is well established for the cod, can be applied to the fresh-water representative of the cod family, the ling.

METHOD

The otoliths of the ling which are flat and oval in shape, were broken at right angles to the long axis and mounted on a cork so that the broken surface could be examined with a binocular microscope. Light was focussed to a point on the side of the otolith just below the broken surface. This method is essentially the same as that used in reading cod otoliths. On examination of the broken surface, an alteration of clear and opaque concentric zones is found surrounding a central opaque region (Figure 1). The opaque rings were counted to determine the age group to which the ling belonged.

INTERPRETATION

Otoliths have been used for more than 30 years to determine the age of cod. Many careful studies have established the validity of the otolith method of age determination. In the cod the combination of a clear and an opaque zone represents a year's growth; which is assumed to be true also for the ling.

[1]Additional common names in current use are burbot, fresh-water cod, lawyer, eel pout, cat lawyer, and others.

A growth curve relating the standard length of each specimen to the number of opaque zones on its otolith is given in Figure 2. Ages are plotted to the nearest fractions of years since the fish were taken over a period of 5 months. The resultant growth curve is quite typical of the growth curves of other teleost fishes.

Figure 1.—The broken surface of a ling otolith showing six opaque rings. Long axis of broken surface approximately 3 millimeters.

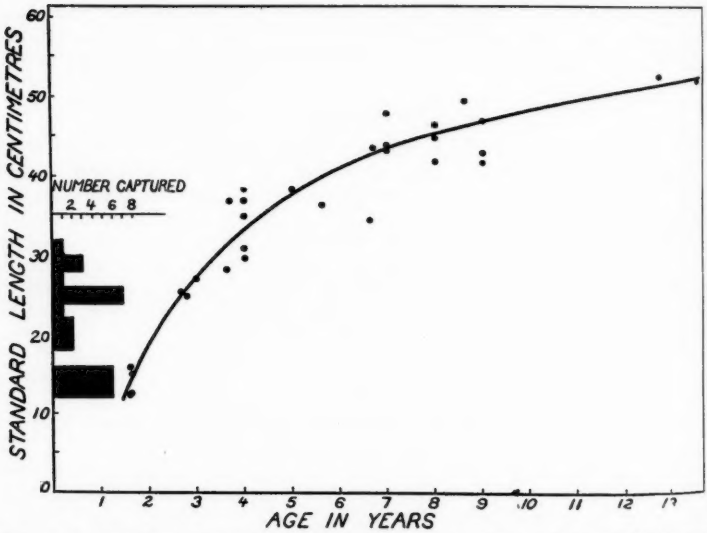

Figure 2.—Standard length in centimeters of ling at various ages and histogram of the length-frequency distribution of individuals in the sample less than 34 centimeters in length. Data secured in 1938.

All otoliths examined had a clear zone at the margin. Since all specimens were taken between late July and late December, the clear zones are believed to be laid down in summer. In the cod the clear zone is indicative of summer growth. Dannevig (1933) described the formation of a clear zone after early August and an opaque zone after early January for the cod, *Gadus callarias* L., of Norway. Zone formation, then, appears to be similar in the cod and the ling.

Further justification for the use of the otolith method in the ling is found in the relationship of a length-frequency histogram to the growth curve. The histogram in Figure 2 shows the standard lengths of the ling less than 34 centimeters long taken in 1938. Two modes are apparent at 14 and 25 centimeters. These modes correspond closely to the average sizes of the fish placed in age-groups I and II by the otolith method. The modes of the older age groups overlap to such a degree that the age cannot be determined from a length-frequency distribution, a circumstance quite typical of many fish populations.

Summary

The thesis that the otolith method of age determination is applicable to the ling is supported by the following facts:

1. Ling otoliths closely resemble cod otoliths for which the method of age determination is well established. Both have a central opaque zone surrounded by alternate clear and opaque concentric rings. The clear zone forms during the summer growing season in both ling and cod.

2. The growth curve of the ling made from otolith readings is similar to that of other teleost fishes.

3. The modes in a length frequency histogram of all the small fish taken during 1938 correspond to the average sizes of age-groups I and II as determined by otolith readings.

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SELECTIVE POISONING OF FISH[1]

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ABSTRACT

When derris root was applied to the warmer surface waters of two small trout lakes, comparatively little seemed to penetrate to the colder, deeper water. Apparently the perch, rock bass, and largemouth black bass were destroyed, with very slight damage to the trout population. The study of the poisoned fish yielded information on fish populations and on habitat selection. The method of selective poisoning is suggested as a means of ridding certain trout waters of undesirable species of fish.

INTRODUCTION

Workers in fish management are recognizing more and more that many bodies of water might be of greater value to the sport fisherman if populations of certain undesirable fish were destroyed (Hubbs and Eschmeyer, 1938). These fish may be predators, such as gars or dogfish; they may be coarse fish, as carp or goldfish, held to be of little value, and possibly detrimental to game fish because of competition for food; or they may be fish of game species, that are out of place ecologically, as perch, rock bass and largemouth black bass are in certain northern trout lakes. These warm-water fish generally make a poor growth in cold waters. If present in large numbers, they may be of distinct harm to the trout, because of food competition and possibly by their destruction of trout fry and fingerlings.

Often these objectionable fish, of one kind or another, are species that have been introduced, in well-meant, but mistaken, attempts to improve fishing. Once the harm is done, usually it is difficult to undo. If the body of water is small, it is sometimes feasible to destroy the existing fish population, and to start over by restocking with desirable species. Usually such methods as seining, dynamiting, and spearing have not proved successful in killing all of the fish. Some small ponds can be drained. However, by far the most generally efficient method thus far devised is the use of some kind of fish poison.

In one of the first attempts to eliminate by poison an unwanted population of fish, copper sulphate was applied to a lake in Vermont, and an extensive, but not entirely complete, destruction of fish was effected (Titcomb, 1914). In more recent years many lakes and ponds have been poisoned, some of them quite successfully. Copper sulphate has been used with fairly good results in Nova Scotia (Catt, 1934; Smith, 1935 and 1938). In Michigan (Eschmeyer, 1937 and 1938), as well as elsewhere, many lakes have been poisoned with derris

[1]Contribution from the Michigan Institute for Fisheries Research.

root. One advantage of derris over copper sulphate lies in the much smaller destruction of fish food organisms (Leonard, 1939; Smith, 1940).

Where the size of the body of water or some other factor renders impracticable the complete destruction of a fish population, an effort often has been made to eradicate or control undesirable species of fish without killing the more desirable ones present. Various methods, such as spearing, netting, and the destruction of young fish, have been used, but usually with little beneficial effect. In certain localities in the southern part of the United States, control of gars by the use of electric shock has been tried, with some degree of success (Burr, 1932).

Probably the first reported experiment in using poison to kill one kind of fish in a lake, while sparing the other fish, is that initiated in Fish Lake, Utah, in 1938, under the direction of Stillman Wright (Davis, 1940, and letter from Dr. Wright). In this lake the Utah chub (*Gila atraria*), which is thought to be detrimental to the brook trout, is killed in large numbers by the application of derris to the large shoal areas at either end of the lake, where the chubs congregate in June and July to spawn. The trout are segregated in the main part of the lake at that time of the year, and are not affected by the derris.

In the lakes with which the present paper deals, derris was used in an attempt to destroy the fish. Because of the small amount of poison used in proportion to the depths and volumes of the lakes and because of low water temperature, the kill was not complete, but was confined to those portions of the lakes in which the poison occurred in lethal concentrations. Certain fish undesirable in trout lakes, namely rock bass, perch, and largemouth black bass, apparently were destroyed entirely, with only a small kill of trout.

Lakes Treated

Two small lakes and a pond on the estate of R. F. Grant, near Vanderbilt, Otsego County, Michigan, were treated with powdered derris root on August 15-17, 1939, by a field party of the Michigan Institute for Fisheries Research. Mr. Grant furnished the derris used in poisoning these lakes, as well as board and room for four men for several days, and in all other ways cooperated with the Institute in performing the work.

Berry Lake has a surface area of 17.8 acres, and Fitzek Lake an area of 6.2 acres. In each lake the maximum depth is slightly over 50 feet; there is an abrupt drop-off, with little shoal area; and the bottom contains considerable marl. Ground seepage and several small spring-fed streams supply the lake.

Connected to Fitzek Lake by an open channel about 300 feet long, is a small body of water, known as Pond 4, with a surface area of 1.6 acres, and a maximum depth of about 10 feet. The bottom consists

largely of muck, and supports a fairly dense growth of rooted aquatic plants. Pond 4 drains into Berry Lake, but a weir prevents the passage of fish from this lake into the pond.

At the time of poisoning, the lakes contained rock bass (*Ambloplites rupestris*), largemouth black bass (*Huro salmoides*), and yellow perch (*Perca flavescens*), as well as rainbow trout (*Salmo gairdnerii irideus*), brook trout (*Salvelinus fontinalis*), and brown trout (*Salmo trutta*). Some years ago lake trout (*Cristivomer namaycush*) had been introduced, and at the time of poisoning a few were present in Berry Lake, and possibly a few in Fitzek Lake. Suckers (*Catostomus c. commersonnii*) were fairly abundant. Other species of fish present in one or both lakes included the pumpkinseed sunfish (*Lepomis gibbosus*), creek chub (*Semotilus atromaculatus*), mud minnow (*Umbra limi*), blunt-nosed minnow (*Hyborhynchus notatus*), brook stickleback (*Eucalia inconstans*), Iowa darter (*Poecilichthys exilis*), barred killifish (*Fundulus diaphanus menona*), golden shiner (*Notemigonus crysoleucas auratus*), and brook lamprey (*Entosphenus lamottenii*).

Application of the Poison

On the morning of August 15, 1939, approximately 175 pounds of powdered derris root (5 per cent rotenone content) were put in Fitzek Lake. The material was mixed with water to form a very thin suspension, which was poured onto the surface of the lake from a motorboat. The boat was run in a crisscross pattern, so that the lake's area was rather uniformly covered. During the following 4 days the dead fish were nearly all recovered from the margin of the lake.

Pond 4 received a small amount of derris root in the overflow from Fitzek Lake, plus an application of 10 pounds on the afternoon of August 15. The dead fish from the pond also were picked up.

On August 17, about 350 pounds of powdered derris root were applied to Berry Lake. Because of the brushy shoreline and abrupt drop-off, no attempt was made at a complete recovery of the fish killed in this lake.

It was not determined to what extent the poison penetrated the lower depths of water. However, a relatively very small number of suckers and trout, which presumably were in the deeper water or at the mouths of spring tributaries, were killed. Not only is derris much less effective in colder water (Leonard, 1939), but it probably does not reach the lower depths in any very appreciable amounts. It is likely that a thermocline prevents the penetration of the poison to the deeper water.

The concentration of derris used therefore may be computed in two ways. Following the usual procedure, the weight of derris may be divided by the total weight of water in the lake, giving the theoretical concentration if the material were distributed uniformly throughout the body of water. However, since most of the derris presumably

remained in the upper layers of water, probably a more accurate method would be to calculate the concentration, assuming uniform distribution above some arbitrary level (in the present case, 20 feet). On this basis, the following comparative theoretical concentrations are obtained. In Berry Lake, 350 pounds of derris root would give a concentration in the total water volume of 0.27 p.p.m., or in the volume above 20 feet of 0.44 p.p.m. In Fitzek Lake, 175 pounds of derris would be equivalent to 0.35 p.p.m. in the total volume, or 0.62 p.p.m. in the volume above 20 feet. In Pond 4, which is all shallow, the 10 pounds of derris used would yield a concentration of 0.56 p.p.m. for the entire volume. The lake volumes were computed from depth-contour maps, based on soundings made through the ice in the winter.

Fish Killed

No attempt was made to count the fish killed in Berry Lake. Large numbers of rock bass and perch were destroyed; also many large-mouth black bass and a few suckers, as well as numbers of various forage fishes, were killed. No dead trout were found.

Table 1 enumerates all of the fish that were picked up from Fitzek Lake and Pond 4. It is probable that a nearly complete recovery

Table 1.—Fish recovered from Fitzek Lake and Pond 4

Species	Numbers	Total weight (pounds)
FITZEK LAKE		
Rock bass	632	36.6
Largemouth black bass	197	25.7
Yellow perch	398	28.4
Subtotals	1,227	90.7
Brook trout	12	0.5
Common sucker	40	11.6
Golden shiner	22	1.4
Creek chub	15	0.2
Blunt-nosed minnow	4,082	12.6
Mud minnow	286	1.9
Stickleback	19	0.1
Iowa darter	61	0.1
Killifish	1	....
Brook lamprey	1	....
POND 4		
Rock bass	688	42.2
Largemouth black bass	173	12.9
Yellow perch	241	29.1
Subtotals	1,102	84.2
Brook trout	4	1.1
Rainbow trout	1	0.5
Pumpkinseed sunfish	4	0.1
Common sucker	271	70.2
Golden shiner	147	9.5
Creek chub	48	4.6
Blunt-nosed minnow	50	0.4
Mud minnow	1,678	10.6
Stickleback	34	0.1
Iowa darter	27	0.1
Totals (Pond 4)	3,366	181.4

of dead fish was made, for very few were observed on the bottom, which was clearly visible at depths to 20 feet.

In view of the results of later netting operations, to be described below, and because the pond is small and shallow, it seems highly probable that all of the fish in Pond 4 succumbed, with the possible exception of some mud minnows or individuals of other small species. It seems likely that all or nearly all of the pumpkinseed sunfish, rock bass, largemouth black bass, and perch in Fitzek and Berry Lakes were killed. It is believed that only a small proportion of the suckers and trout, and possibly of the creek chubs, were affected. It is not known how complete was the kill of the small species of fish, but it is possible that the percentages were fairly large, since most of these fish would have been in shallow water at the time of poisoning.

Therefore, in considering Table 1, it may be assumed that the numbers and weights of fish from Pond 4 represent fairly accurately the fish population of the pond at that time. Likewise, the figures for rock bass, largemouth black bass, and perch from Fitzek Lake probably are substantially correct values for these fish in the lake; the values for suckers and trout are not (as numbers of these fish were taken in subsequent netting); and those for the remaining species are doubtful. Therefore, for this lake, totals would be somewhat meaningless, and hence are omitted from the table. The subtotals for the three first-named species are given, for purposes of comparison with Pond 4.

It is of interest that at the time of poisoning the pond, even though it is much smaller, contained more total pounds of rock bass and perch than did the lake, and of rock bass there was a larger number in the pond. In addition, the pond contained half as many largemouth black bass as the lake. Apparently at that time the conditions in the warmer, more shallow, pond were more favorable to these three fishes than were those in the lake.

Furthermore, very many more mud minnows and golden shiners were taken from Pond 4 than from Fitzek Lake. Possibly some mud minnows in the lake were not killed or were not recovered, but it is presumed that most of the golden shiners in the lake were in the shallow water at the time of the poisoning, and therefore probably were killed. Thus it seems that there was a decided preference on the part of the golden shiners for the ecological conditions of the pond.

On the other hand, the blunt-nosed minnow was much more abundant in the lake than in the pond. This fish is known to favor waters with scanty vegetation; and the vegetation in the lake was quite sparse in comparison with that in the pond.

Effectiveness of the Selective Poisoning

Three 125-foot gill nets, of mesh graded from 1½ to 4 inches stretched measure, were fished in Berry Lake during the night of August 18-19, 1939, about 30 to 40 hours after the derris root had been

put into the lake. These nets took only 2 small perch, 1 brook trout, and about 30 suckers.

From October 16 to October 18, 1939, a total of 10 individual overnight sets of the same type gill net was made in Berry Lake, in addition to 1 set of a small fyke net. Altogether, several suckers, 3 brook trout, 2 brown trout, and 2 lake trout were taken. During the same period, 3 gill-net sets in Fitzek Lake yielded 4 rainbow trout, 3 brown trout, 1 brook trout, and several suckers. One gill net set overnight in Pond 4 took no fish.

During the night of July 1-2, 1940, 2 gill nets of the same type and 1 fyke net were fished in Berry Lake, and 2 gill nets were set in Fitzek Lake. A few suckers were the only fish taken in Berry Lake; the nets in Fitzek Lake yielded 10 brook trout, 1 rainbow trout, 1 brown trout, and a few suckers.

Except for the two perch that were taken in gill nets shortly after the poisoning, no perch, rock bass, or largemouth black bass have been taken in either of the lakes or the pond since the poisoning, nor have fish of these species been observed in several careful inspections of shoal areas. Apparently the fish of these three species were almost entirely, if not entirely, eliminated by the poison.

Thus the "partial" poisoning of the populations of fish in Berry and Fitzek Lakes seems to have been rather successful. It is believed that this method of killing a selected part of the fish population of a lake will become a very useful tool in fish management, particularly in certain trout waters which are now overrun with warm-water fish. If a lake is of sufficient depth that a definite segregation of the two types of fish occurs, it appears to be feasible to destroy the warm-water species largely or completely without doing serious damage to the cold-water fishes. Experiments are planned to determine more precisely the depth preferences of various fishes, and the effect of stratification of the water on the dispersion of powdered derris root

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HOW FISHERY MARKET NEWS INFORMATION IS USEFUL IN CONSERVATION

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ABSTRACT

The Fishery Market News Service is providing widespread benefits to the fishery marketing trade and to consumers in the United States. In addition to the benefits in economic well-being and health provided these two groups, the Market News contributes to the public welfare by assisting in the conservation of the fishery resources. Through reduction of wasteful processes in fish utilization and the provision of records of value in fishery management, the Market News effects wiser use of these resources.

On February 14, 1938, there was instituted, in New York City, a new Government fishery activity, the Fishery Market News Service of the Division of Fishery Industries, Fish and Wildlife Service, U. S. Department of the Interior, patterned after the market news service operated by the Department of Agriculture. The need for such fishery work had been recognized for many years by American legislators but it was not until the Seventy-Fifth Congress that funds were provided specifically for the establishment of this service. Later that year and in succeeding years other offices were established so that today there are offices in New York, Boston, Chicago, Seattle, New Orleans, and Jacksonville. From these the Service issues daily, weekly, and monthly reports of market movements and price quotations of fish and fishery products by mail and radio. Data are disseminated concerning vessel landings, rail receipts, cold storage holdings, shrimp and salmon packs and stocks, and other information vital to producers, shippers, processors, distributors, retailers, and consumers. Consumer radio programs are being added and other services are being planned for inclusion in the routine as time and funds permit. Since the market news was instituted, the value of the activities has been attested by all segments of the fishery trade in scores of commendatory letters.

Through use of fishery market news information there has been a diminishing of the disorder which in the past has characterized fresh and frozen fish marketing in many areas of the United States. The tendency of this service is to eliminate uncertainties that cause accumulations of surpluses and otherwise limit production and distribution. Through the interpretation of volume and price data the current market trends may be recognized and marketing activity altered accordingly. The alteration of fish-marketing activities resulting from the operation of the Fishery Market News Service has been

of considerable magnitude, and has assumed a value in dollars and cents to the producers and handlers of fish and fishery products. The American consumer has also benefited insofar as he has received fish in better condition, in greater variety and abundance, and at more satisfactory prices.

While the Fishery Market News Service is yielding direct benefits in profits to the fishery trade and in savings and health to American consumers, it is also of value in the conservation of the fishery resources. It has taken its place and promises to be of increasing value among Government activities contributing to wise utilization of the resources. This it accomplishes in two ways, (1) through reducing waste in the use of fish and fishery products by the fish trades and in the home; and (2) through originating and compiling records of importance in the management of our fisheries. The first effect, reduction of waste of fish and fishery products, is obtained chiefly through a decrease of spoiling or "dumping" due to the elimination of many marketing uncertainties and the education of consumers in the use of fish and fish products. Through reduction of waste any given demand for any fishery products can be filled with a lessened drain on the resources. Waste of potential food supplies may be reduced also by the improved opportunities presented the producer. Many fishery resources which cannot be exploited profitably where wasteful production or marketing practices are in use may become the basis of industry and income if orderly procedures are adopted. By this elimination of wasteful processes the Market News insures that the yield from the resources become dedicated to a more complete, and therefore a wiser use.

The second conservation effect of the Fishery Market News Service is accomplished through the provision of records of value in fishery management. While the records of this service were originated for day to day use in the operation of the various fish trades to provide for more orderly marketing, they are and will be available as aids to fishery management. The person entrusted with management of a fishery resource endeavors to determine the magnitude of the fish population of certain waters and the yield of fish that this population can withstand without depletion. Although careful and continuous biological studies are necessary, these alone do not provide sufficient information for sound management of the fishery. Our control of the resource is exercised chiefly through regulation of the commercial or sport fishing effort, and we must therefore know the magnitude of that effort and upon what factors it depends. Fundamental research for progressive fishery management cannot stop with biology, fish culture, and habitat improvement. It must go also into technology and economics, and possibly into human ecology. Fishery management research consists of accurate observations and experiments, and the formulation of legitimate and precise conclusions therefrom. The investigator takes inventory of the resource, studying its character,

the character of the fishing effort, and the use of the products of the fishery. With this as a background he determines (1) what portions of the fish population can be spared to obtain the greatest public benefit from the resource consistent with future needs; (2) how artificial aids may be supplied to rehabilitate the resource or otherwise improve its condition for serving our food or recreation needs; (3) the character and magnitude of the fishing effort needed to remove the desired catch with least damage to the resource, with full recognition of factors relating to operating costs, labor requirements, and other elements; and (4) what changes in fish utilization are desired to obtain maximum value from the yield. Such research provides the necessary basis for the selection, formulation, and prosecution of adequate control of fishing effort and fish use.

Any source that provides or can provide any of the essential links in the required chain of research processes is of value to fishery management, and in this capacity the records of the Fishery Market News Service may be definitely classified. For these records in their present form are usable either as primary or corroborative data and their use will be improved and expanded as rapidly as facilities and the growing reliability of the statistics permit.

The manner in which market news records can be of value in fishery management may be exemplified by analysis of records compiled by the Boston office. For this purpose, certain records of landings at the Boston Fish Pier are presented to show, (1) how they are qualified to assist in identifying the economic changes resulting from removal of a portion of the fishing effort, and (2) how they can provide indices which aid in determining the condition of some fishery resources exploited from Boston. Figures 1 and 2, which show graphically the information on Boston Fish Pier sales tabulated in Tables 1 and 2 illustrate how the records provide a picture of a relationship between weight of fish landed and the prices paid to the fishermen and the effect of removal of fishing effort on that relationship. An inverse relationship between the weight of landings and unit prices is made evident. This relationship is sufficiently pronounced and consistent to allow its use within reasonable limits in forecasting the effects on fish prices of a change in fishing effort.

The greatest departure from normal conditions in Boston receipts of the last 3 years occurred between March 15 and June 28, 1940, when the large otter-trawl vessels operating out of Boston were inactive because of labor controversies. Figure 2 is designed to show the deviation of the portion of 1940 that was affected directly by the Boston labor controversies from what may be considered as normal trends of 1938 and 1939. This graph emphasizes the relationship between weight of landings and unit prices. Lent occurred in 1940 from February 7 to March 24; in 1939, from February 22 to April 9; and in 1938, from March 2 to April 17.

Interpretation of such records can aid in identifying and forecast-

Table 1.—Sales of fish by months at the Boston Fish Pier, January, 1938, to July, 1940, inclusive

Month	1938			1939			1940		
	Weight in pounds	Cents per pound	Total value	Weight in pounds	Cents per pound	Total value	Weight in pounds	Cents per pound	Total value
January	22,844,563	2.96	$676,199	17,512,586	3.18	$556,900	20,942,657	3.58	$749,747
February	22,465,714	2.92	655,999	21,674,019	2.95	639,384	21,779,645	3.62	788,423
March	29,671,436	2.66	789,260	26,003,492	3.16	821,710	18,417,460	4.36	803,001
April	28,028,580	1.95	546,557	24,379,789	2.38	580,239	13,326,701	4.23	563,719
May	29,904,139	1.78	532,294	27,760,726	2.05	569,095	14,513,889	3.54	513,792
June	27,733,624	2.01	557,446	21,019,904	2.65	557,027	16,793,705	3.09	518,925
July	22,993,546	2.35	540,348	23,132,089	2.42	559,797	28,387,994	2.51	712,539
August	28,160,432	2.31	650,506	25,683,334	2.69	690,882	.....	.....	.....
September	22,194,425	2.78	616,997	23,207,617	2.86	663,738	.....	.....	.....
October	22,268,543	2.69	599,024	21,395,932	3.34	714,624	.....	.....	.....
November	22,166,893	2.40	532,005	21,154,325	3.17	670,592	.....	.....	.....
December	21,609,932	2.96	639,654	22,059,299	2.92	644,132	.....	.....	.....

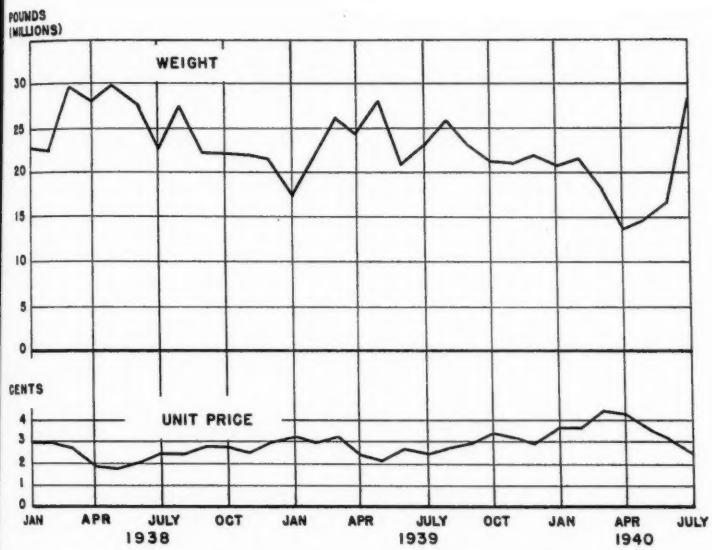

Figure 1.—Total sales of fish by months at the Boston Fish Pier, January, 1938, to July, 1940, inclusive

Table 2.—Percentage deviations by months of January to July, 1940, sales at the Boston Fish Pier, from sales for the corresponding months in 1938 and 1939

Month	Weight		Unit price		Value	
	1938	1939	1938	1939	1938	1939
January	—8	+20	+21	+13	+11	+35
February	—3	....	+24	+23	+20	+23
March	—38	—29	+64	+38	+2	—2
April	—53	—45	+117	+78	+3	—3
May	—52	—48	+99	+73	—3	—10
June	—40	—20	+54	+17	—7	—7
July	+23	+23	+7	—14	+32	+27

ing the effects of enforcement of regulations, labor shortages or surpluses, vessel or gear adjustments, publicity campaigns, price increasing or lowering, and other factors available for direct or indirect manipulation by the fishery manager.

Other market news records may in themselves or in combination with other information indicate the condition of a resource. Figure 3, based on data in Table 3, provides an index on the condition of the haddock fishery prosecuted from Boston in offshore areas. The proportion, by weight, of scrod haddock in the total landings of haddock

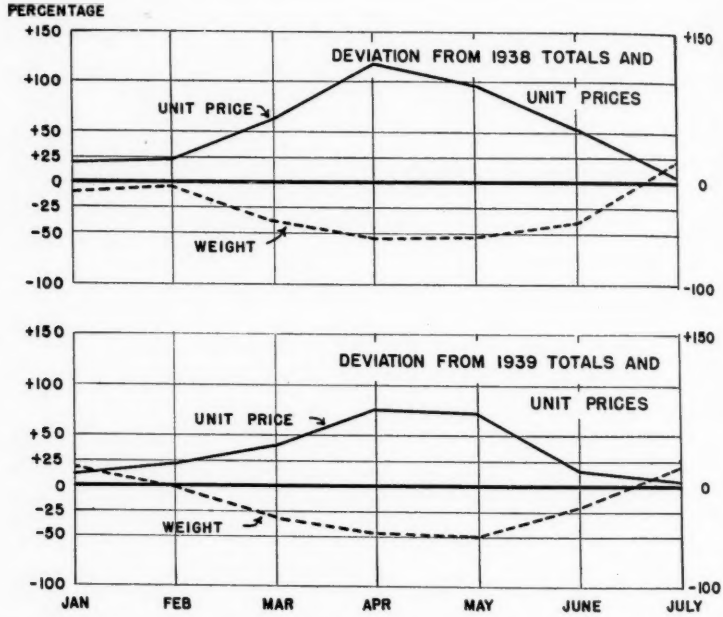

Figure 2.—Percentage Deviation by months of 1940 sales of fish at the Boston Fish Pier, compared with sales of 1938 and 1939, January to July, inclusive

at the Boston Fish Pier is indicative of the relative abundance of scrod haddock in the offshore haddock population. A preponderance of scrod in the catch would probably indicate that the adult stock was badly depleted, while a preponderance of adult stock would indicate that unsatisfactory conditions of stock replacement existed. In either case it would be made evident that remedial measures should be instituted to better the condition of the fishery. The cause of the unbalanced condition of the population and the nature of remedial measures that should be undertaken would probably not be evident from the market news records alone and these would have to be established through knowledge of biological conditions on the fishing banks and a further analysis of catch statistics.

It is yet too early, too soon after the inception of the Fishery Market News Service, to prophesy the eventual value of its records to conservation. The present records are being used to a limited extent by today's investigators. There can be no doubt, however, but that

Table 3.—Sales of haddock at the Boston Fish Pier, January, 1938, to July, 1940, inclusive, for offshore vessels only

Month	1938			1939			1940		
	Total haddock (pounds)	Scrod haddock (pounds)	Percentage of scrod	Total haddock (pounds)	Scrod haddock (pounds)	Percentage of scrod	Total haddock (pounds)	Scrod haddock (pounds)	Percentage of scrod
January	6,191,030	940,975	15.2	7,095,295	1,959,745	27.6	8,575,791	3,079,033	35.9
February	10,808,700	1,487,400	13.8	9,297,215	2,805,650	30.2	10,131,095	3,205,550	31.6
March	14,532,395	2,059,220	14.2	13,449,410	3,514,995	26.1	9,101,467	2,314,777	25.4
April	14,912,420	2,735,880	18.3	10,694,890	3,065,240	28.7	8,146,348	2,040,453	25.0
May	8,704,553	1,710,583	19.5	12,247,410	3,810,235	30.9	8,392,891	1,951,261	23.4
June	9,455,615	2,892,505	30.6	8,518,350	3,163,450	37.1	7,551,273	2,033,278	27.0
July	7,765,970	3,084,930	40.0	10,749,965	4,773,505	44.4	12,771,125	4,915,445	38.5
August	12,382,090	7,605,740	61.4	12,310,580	6,385,225	51.9	.....	.....	.....
September	10,603,175	6,263,325	59.1	9,840,025	4,745,525	48.2	.....	.....	.....
October	7,197,870	3,105,930	43.5	9,018,260	4,188,310	46.4	.....	.....	.....
November	6,326,187	2,901,832	45.9	5,352,280	2,147,145	40.1	.....	.....	.....
December	6,176,030	2,179,890	35.3	7,985,125	2,821,460	35.3	.....	.....	.....

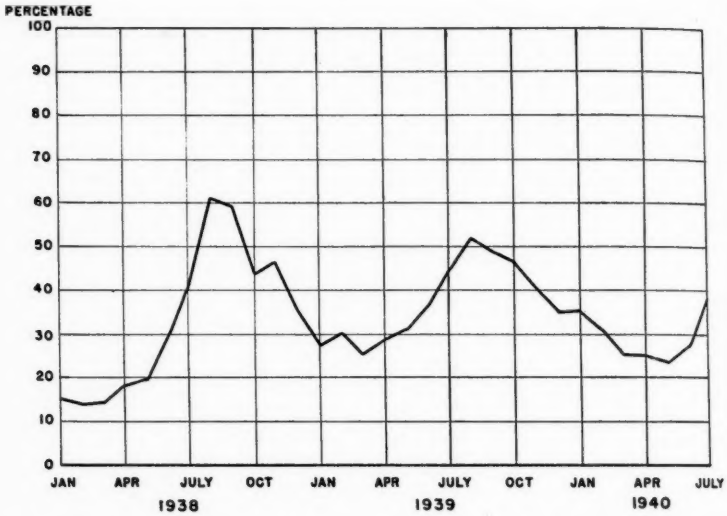

Figure 3.—Percentage by months of scrod haddock in total haddock from offshore fishing grounds, sold at the Boston Fish Pier, January, 1938, to July, 1940, inclusive

the possibilities for their increased use in resource management are considerable. As the Fishery Market News Service grows in coverage and functions, its effect in the elimination of waste in our fish uses will also increase. The time should not be far distant when the contributions of this service will be anticipated and planned for in conservation programs governing the use of many of our important fishes.

POSSIBILITIES FOR THE PROMOTION OF THE COMMERCIAL FISHERIES OF PUERTO RICO

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ABSTRACT

The annual importation of fish into Puerto Rico amounts to about 36 million pounds as compared to a local production of only 3 million pounds. The chief impediments to a greater production and consumption of fish from Puerto Rican waters are the inadequate boats and gear of the fishermen and the faulty systems of handling and distribution. Better facilities for refrigeration are particularly needed. The Insular and Federal Governments are now cooperating in a program for the development of the fisheries of Puerto Rico in both the technological and economic aspects. Benefits to be expected from an expansion of the Puerto Rican fisheries include increased local trade and employment, not to mention the safeguard provided against a shortage of food under conditions of war.

In proportion to its land area, Puerto Rico is one of the most heavily populated areas of the world. The island is in great need of intensive development of all its natural resources. Most of the food consumed is imported from the United States or foreign countries. Last year more than 36 million pounds of fish products were imported into Puerto Rico at a cost of nearly 2 million dollars. Of this amount, 30 million pounds came from Newfoundland in the form of codfish.

It is possible that the present war crisis may develop a food shortage in Puerto Rico. Privations of the World War days are still vivid in the minds of Puerto Ricans. There were times when stocks of staple foods were all but exhausted in the island. Ships that had been regularly bringing supplies were transferred to carry war cargoes and schedules were frequently disrupted. The present world conditions indicate that this situation may occur again. Steps should be taken immediately to prevent a crisis with respect to the supply of food.

So far, little attention has been paid to the development of the commercial fisheries of Puerto Rico. There are around 2,500 persons engaged in commercial fishing on the island. The economic condition of these workmen of the sea is very poor, and they lack means to improve their inadequate equipment.

A score of years ago an attempt was made by the Government to promote the expansion of the fishing industry, but due to inadequate organization and other factors, the attempt was a failure. A new long-range plan is being developed under the supervision of experienced and practical fishery experts in cooperation with the Insular and Federal Governments.

The fisheries of Puerto Rico can be divided into four definite areas: Western coast, southern coast, eastern coast and northern coast. Of these areas, the eastern, western and southern, offer the greater possibilities for the promotion of commercial fishing. They have good spawning and fishing grounds, well protected bays, regular sea bottom, and calm weather.

In 1930, the fishermen of Puerto Rico reported an annual catch of 3,080,100 pounds having an approximate value of $207,085. This amount can easily be increased many times if fishing is organized and better boats and fishing gears are provided.

At present, island fishermen use the same types of boats and gear used during the Spanish era. Over 90 per cent of the boats used are small and poorly constructed and have a limited cruising radius. The fishing gears used include haul seines, gill nets, fish pots, cast nets, weirs and hand lines. The gear, with the exception of hand lines and fish pots, can be used only at a short distance from shore. Therefore, due to the lack of proper equipment, open-sea fishing is not carried on off Puerto Rico. It is a well-known fact that almost every month of the year large schools of migratory fish, such as tuna, Spanish mackerel, kingfish, bonito, etc., travel along the coasts of Puerto Rico but can not be caught due to lack of adequate open-sea fishing gear.

There is a constant supply of fish in the waters of Puerto Rico and there is a heavy demand for fish. The inhabitants of Puerto Rico consume around 40 million pounds of fish a year. This total represents a per capita consumption of 17.6 pounds. Puerto Ricans do not consume more fresh fish because they are afraid of it. The reasons for this failure to consume more fresh fish are the lack of handling facilities and the resulting poor quality of the product. Most of the fish is sold without being cleaned, and retail refrigeration has been virtually unknown until very recently. When fish reached the consumer it was often stale.

The main problem in the promotion of the commercial fisheries of Puerto Rico may be divided into two important phases: (1) The necessity of providing adequate facilities such as better boats and modern fishing gear, to obtain a larger supply of fish, and reduce the wholesale price; and (2) the establishment of a more rapid system of distribution with adequate refrigeration facilities at all times.

The first step in the development of commercial fisheries will be the construction of a fishery products laboratory at Mayaguez. The P.W.A. has allotted $25,000 for the project to the Fish and Wildlife Service of the U. S. Department of the Interior. In addition to the construction of the laboratory, it is of the utmost importance that strictly commercial aspects of the fishery be considered. Toward this necessity, the Insular Government is working out a plan whereby the establishment of fishing cooperatives will be encouraged. Refrigeration plants are contemplated to serve the more important fishing centers of the island and methods of handling fish are to be reorganized.

Although the primary object of the promotion of the industry is to make fuller uses of food reserves of fish, the Government hopes to attain two incidental but equally important objectives along the way. It will be made possible for Puerto Rico to take from the sea emergency rations should a situation develop through war conditions that might threaten the normal food supply. Anyone familiar with Puerto Rico and its labor problems immediately would observe also that a thriving fishing industry will prove to be a valuable source of employment. The unemployment problem in the island is acute and industrialization, of whatever kind, is of very great significance to thousands who are not now able to find continuous employment. For Puerto Ricans, the development of commercial fisheries represents a supply of much needed food, the creation of badly needed employment and a safeguard against possible scarcity of food under war conditions.

Discussion

Mr. R. H. Fiedler: As Mr. Bonnet has indicated, the Fish and Wildlife Service plans to erect a laboratory in Puerto Rico. It is to be built on land donated by the University of Puerto Rico at the College of Agriculture and Mechanical Arts at Mayaguez. In one respect the undertaking will be unique in that we are to have at the laboratory a staff consisting of a biologist, a technologist and an economist. We hope to find out where the fish are, how to capture them, how to preserve them and how to get the people of Puerto Rico to eat them. We believe it is unusual in a fishery laboratory to cover all three or four phases of fishery research.

A MODIFIED SCALE PROJECTOR

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ABSTRACT

A commercial utility projector, the *Promar*, is modified in design and housed in a special cabinet to facilitate the examination of fish scales. A light adjustment control is introduced. The microscope is fixed in an upright position and the beam of light is deflected to the table surface in front of the observer by two mirrors.

The scale projection machine described here is an adaptation of a commercial projector known by the trade name of *Promar* (Clay-Adams Company, Inc., 117 East 24th Street, New York—price, 1939, $169.00, f.o.b. New York). The adaptation has been made to facilitate the routine examination of fish scales in general and of herring (*Clupea pallasii*) scales in particular, but the modified machine may also be used to advantage for general microscopic projection where a small clear image is required.

The unmodified *Promar* projector consists of a microscope pivoted on a bar which is clamped to the upright rod of a tripod stand. A light attachment (6 or 7 volt, 6 ampere lamp, with rheostat in 110- or 220-volt circuit) replaces the ordinary microscope mirror to provide illumination. Among other adjustments, there are two knob-screws in the light housing which are primarily for centering the light, but which may be used for altering the angle of incidence of the beam during examination of the object. The *Promar* is usually used in an inverted position so that the image falls on the table top in front of the operator.

There are several disadvantages to this customary set-up when projecting herring scales. The machine is not stable. A darkened room is necessary. Clips are required to hold the slide in position on the inverted stage. These cause particular inconvenience when several scales are mounted on one slide and the latter is moved frequently. The knob-screws for adjusting the light become too hot to handle and with constant use they soon wear out. In addition, at the particular magnification used (X20) and with the particular combination of lenses (X5 ocular; 48 millimeter objective) they are too high above the table (25 inches) for convenient adjustment. The difficulties of light adjustment are a serious drawback in reading herring scales for it is frequently necessary to sweep the beam back and forth across the scale to locate the annuli. It might be pointed out that these inconveniences are encountered in using the *Promar* for a specific purpose—the routine examination of herring scales from several thousand

fish each year. No criticism of the design of the *Promar* as an instrument for general projection is intended.

Several efforts have been made over a period of years to incorporate the projection apparatus into a unit specially adapted for scale projection. The final product is described briefly in the following paragraphs and is illustrated by Figures 1 and 2.

The *Promar* microscope unit is housed in a special cabinet which is 30 inches wide, 22 inches deep, and 46 inches high. This consists essentially of a table which is enclosed on the two sides, back and top. The inside surfaces are painted black. A utility shelf may be fastened to the inside rear wall. The material for building the cabinet (table surface, 1-inch stock covered with three-ply; top and braces, 1-inch stock; frame 2- by 2-inch stock; sides and back, three-ply) costs less than 5 dollars.

The microscope is mounted solidly in an upright position within the cabinet. The stage rests on the table surface, through which a hole is cut to accommodate the frame, base, and light attachment. The adjustment knob-screws of the light attachment are removed and the

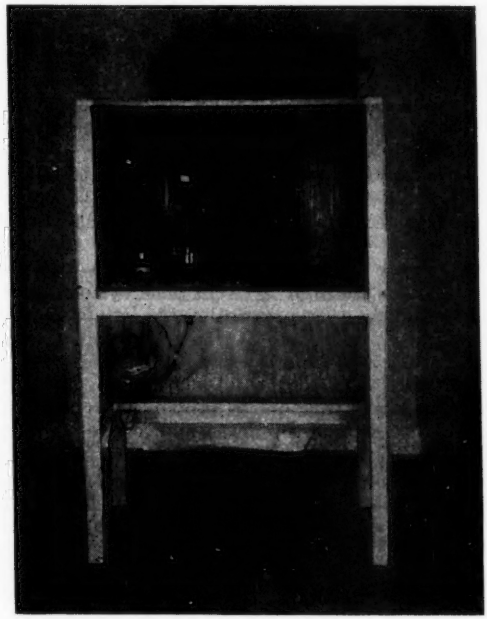

Figure 1.—Photograph of the modified scale projector

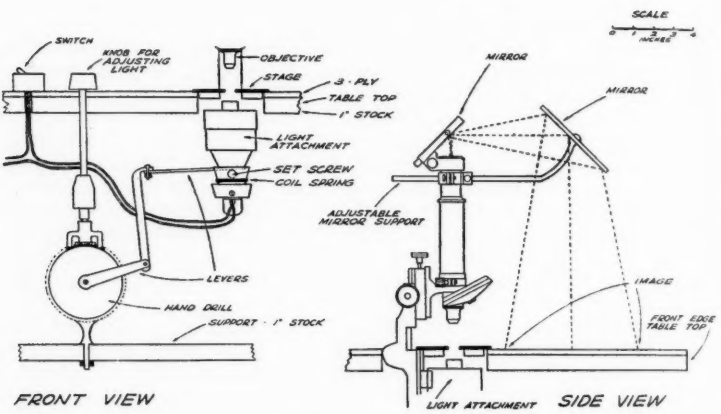

Figure 2.—Semi-diagrammatic drawing of the light adjustment assembly and mirror arrangement of the modified scale projector

frame behind the light is tapped and threaded to accommodate a large flat-headed set screw. The light housing is kept in contact with this set screw by means of a coil spring which encircles both housing and frame. By adjusting the set screw the light may be centered in one plane. A metal strap or ring is fixed around the light housing and, by means of a series of levers, is connected to the arm of an ordinary hand drill which is fastened adjacent to the light. One end of a rod is inserted in the chuck of the drill and to the other end, which projects vertically through the table surface, is attached a radio-cabinet knob. By turning the knob, the light is swept back or forth across the field in one plane. A switch, conveniently located beside the knob, controls the light current.

At the ocular end of the microscope, a small swivel mirror and clamp (supplied with the instrument) is attached. Here also, a second swivel mirror (2¾ by 5 inches) is supported by means of a metal arm and clamp. The distance of the second mirror from the first may be adjusted by means of a set screw in the clamp which holds the arm in position. The second mirror may be procured and its supports made at small cost (2 dollars plus labor, or less). The second mirror is arranged similar to a camera lucida, which may be substituted if available. The beam of light, passing upward through the objective and ocular, is deflected by the first mirror through an angle of 90° toward the operator. It is then deflected downward to the table surface through another angle of 90° by the second mirror. Focusing is readily accomplished in the usual manner. Magnification is altered

by changing lenses and, within limits, by changing the length of the arm holding the second mirror. With proper adjustment and good mirrors, distortion is negligible.

The table top rests on ledges within the cabinet. On removing the light-adjustment knob and one of the pins which connect the levers in the light-adjustment assembly, the table top, with the projection apparatus, may be quickly removed from the cabinet for repairs, or for re-assembly on the tripod base.

With the modified projector all of the inconveniences pointed out in a preceding paragraph have been overcome. The light adjustment knob and control switch are close at hand. The stage is in an upright position and the slide can be moved freely. A clear image is obtained on a piece of white bristol board on the table surface in front of the operator, who sits at the open front of the cabinet. If the machine is placed with its back toward the window or source of light, it may be used without darkening the room. Scale measurements may be made directly and conveniently. In practice, however, a drawing of one scale of each fish showing annuli and scale outline is made on scratch paper and is filed for future reference and measurement. Peculiar or outstanding scales may be photographed in a partially darkened room by the use of ordinary photographic paper which is held in a frame on the table surface of the projector. The negative print thus obtained is quite satisfactory for most purposes, including reproduction in publications.

The author wishes to thank Mr. L. Quickenden of the Pacific Biological Station for assistance in the mechanical design and construction of this and prior models of the modified projector, and Dr. R. V. Boughton for assistance in working out the optical arrangement.

AGE, GROWTH, AND PRODUCTION OF THE YELLOW PERCH, *PERCA FLAVESCENS* (MITCHILL), OF SAGINAW BAY

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ABSTRACT

Ages were determined and individual growth histories computed from the examination and measurement of scales from 820 yellow perch collected in 1929 and 1930. Calculated lengths greater than 101 millimeters were computed on the assumption (supported by empirical data) that the ratio of body length to scale length is constant. Lengths below 101 millimeters were determined with the aid of an empirical curve of the body-scale relationship of small fish.

Yellow perch of age-groups III and IV (in the fourth and fifth years of life) made up the bulk of the collection (78 per cent). Females grew slightly more rapidly than males, but members of both sexes attained the legal length of 8½ inches during the fourth year of life, just as they were entering on the period of most rapid growth in weight. The greatest growth in weight of both sexes occurred in the sixth year of life. In the combined samples of the two years the females exceeded the males in abundance in the ratio, 296:100.

The weight of the Saginaw Bay yellow perch was found to increase as the 3.117 power of the length. The relative length of the tail decreased with increase in the length of the fish.

The Saginaw Bay yellow perch is now far less abundant than it was in the early years of the fishery. The average annual production of 548,000 pounds over the period, 1917-1938, was only 28 per cent of the earlier (1891-1916) "normal" annual production of 1,961,000 pounds. A detailed analysis of statistical data available for more recent years made possible a description of annual fluctuations in the abundance and production of yellow perch and in the intensity of the yellow perch fishery in Saginaw Bay over the period, 1929-1938.

INTRODUCTION

The yellow perch, *Perca flavescens* (Mitchill), is one of the most common and most highly prized of the fresh-water fishes of the northeastern United States and southeastern Canada. The species finds favor with anglers both because of its excellent quality and because of the ease with which it may be captured. Yellow perch taken in the commercial fishery ordinarily find a ready market at a good price.

Saginaw Bay is the most important center of commercial production of yellow perch in the State of Michigan waters of the Great Lakes and, next to Lake Erie, contains the most productive perch grounds in the entire Great Lakes. The yellow perch is not, however, the leading species in the commercial fishery of the Bay. During the years, 1934-1938, the average annual catch of perch in Saginaw Bay was exceeded by the catches of lake herring, wall-eyed pike, suckers, and carp, in that order of importance.

Numerous studies have been made of the age and growth of perch in small inland lakes, but to date only two publications have appeared dealing with the growth of perch in Great Lakes waters. Both of

these small papers (Harkness, 1922; Jobes, 1933) were concerned with the Lake Erie yellow perch. A comprehensive life-history study of the Lake Erie perch (Jobes, MS.) will be published in the near future. Nothing has been published concerning the growth of the yellow perch of Lake Huron.

Materials and Methods

The investigation of the age and growth of the Saginaw Bay yellow perch has been based on the examination and measurement of the scales of 820 fish taken by experimental pound nets (mesh sizes—2, 2½, 2¾, and 3 inches, stretched measure as manufactured) during the spring and early summer fishing seasons of 1929 and 1930. These nets were set near Sand Point, north of Bayport, Michigan. The study of the length-weight relationship was made from the data for 1,483 perch captured in experimental pound nets near Sand Point in the years, 1928-1930, and in commercial trap nets off Bay City, Michigan, in 1934. The relationship between total length and standard length was determined from measurements of 1,411 fish collected in the same 4 years and from the same nets. Scattered collections totalling 512 fish captured at various times in the season from April to November in the years, 1921, 1925-1927, 1930, and 1934 were employed for the investigation of the relationship between body length and the anterior interradial measurement of the scale. Of these 512 perch, 332 were taken by small hand seines, mostly along the south shore of the Bay. The remaining 180 fish were captured by commercial trap nets off Bay City.

All fish except 332 preserved specimens used in the study of the body-scale relationship were weighed and measured when fresh. Lengths were measured with a steel tape and were recorded to the nearest millimeter. Weights were recorded to the quarter ounce. The preserved fish were not weighed; their lengths were corrected for shrinkage by the factor, 1.005, which has been determined empirically.

The scales employed for age determinations were mounted on standard 3- by 1-inch microscope slides in a glycerin-gelatine medium and were examined and measured on a micro-projection apparatus at the magnification, X 40.7. Ages were designated by Roman numerals corresponding to the number of annuli on the scales. For example, yellow perch with one annulus (in the second year of life) are members of age-group I.

Commercial Production of Yellow Perch in Saginaw Bay

Data are available on the commercial production of perch in Saginaw Bay for the 18 years, 1891-1908, and for the 23 years, 1916-1938[1]

[1]The records for the years, 1891-1908 and 1929-1938, were compiled from State of Michigan records on file in the Great Lakes laboratory of the Fish and Wildlife Service. The data for the remaining years were obtained from the following reports published by the State of Michigan: 1916-1919, biennial reports of the State Game, Fish and Forest Fire Department of the Public Domain Commission; 1920-1928, biennial reports of the Department of Conservation.

Table 1.—Annual production of yellow perch in Saginaw Bay, 1891-1908 and 1916-1938

Year	Production (pounds)	Year	Production (pounds)
1891	1,102,650	1920	803,725
1892	1,801,600	1921	659,254
1893	1,691,600	1922	461,111
1894	2,013,500	1923	572,817
1895	1,754,300	1924	444,064
1896	1,577,300	1925	414,137
1897	1,539,000	1926	314,848
1898	2,187,650	1927	112,711
1899	2,804,200	1928	192,008
1900	3,452,800	1929	441,373
1901	3,379,200	1930	611,679
1902	2,384,500	1931	655,542
1903	2,069,200	1932	587,532
1904	1,529,200	1933	330,877
1905	1,571,700	1934	398,555
1906	1,747,900	1935	836,784
1907	1,935,000	1936	1,073,861
1908	1,085,877	1937	351,382
1916	1,637,691	1938	326,824
1917	642,840	Average, 1891-1938	1,203,204
1918	789,287	Average, 1891-1916	1,961,309
1919	1,018,292	Average, 1917-1938	548,477

(Table 1). On the basis of the available statistics it is possible to speak of an early period of high production (1891-1916) and of a recent period of relatively low yield (1917-1938). The annual production fell below 1,500,000 pounds only twice (1891 and 1908) in the former period, and exceeded 2,000,000 pounds in 7 of the 19 years for which there are records. In the latter period, however, the commercial catch rose above 1,000,000 pounds only twice (1919 and 1936) in 22 years and was less than 500,000 pounds in 11 years.

Production was by no means uniform within the two periods. In the earlier period, for example, the annual catch was consistently above 2,000,000 pounds for the 6 consecutive years, 1898-1903, and was above 3,000,000 pounds in both the record year of 1900 and in 1901. By comparison the catch was relatively low in certain other periods, as 1895-1897 and 1904-1906. In the recent period, 6 consecutive years (1924-1929) had productions below 500,000 pounds, whereas the catch was relatively much higher in other years (1918-1920, 1935-1936). These fluctuations do not, however, invalidate the separation of the history of production into an early and a modern period.

The extent to which the production of yellow perch in Saginaw Bay has fallen off since 1916 can be brought out more clearly by comparisons in which recent catches are expressed as percentages of the earlier or "normal" yield. If the average 1891-1916 catch is given the value of 100, the average annual yield for the 22 years, 1917-1938, may be determined as 28. The annual production of the modern fishery is therefore 72 per cent below the early "normal." Even the excellent catch of 1936 was only 55 per cent of the normal. The average production for the most recent 10-year period, 1929-1938, in spite of good years in 1935 and 1936, was only 29 per cent of normal.

Table 2.—Production of yellow perch in Saginaw Bay, 1929- 1938, according to gear and total production and fishing intensity in each year, expressed as a percentage of the 1929-1934 average

Year	Production in pounds by gear						Total	Production as percentage of 1929-1934 average	Fishing intensity as percentage of 1929-1934 average
	Small-mesh gill net	Pound net	Shallow trap net	Fyke net	Seine	All others[1]			
1929	25,689	54,985	269,132	46,524	27,241	17,802	441,373	88	78
1930	74,171	51,262	383,059	63,104	37,332	2,751	611,679	121	111
1931	74,277	47,358	431,454	68,492	29,784	4,177	655,542	130	134
1932	28,351	22,754	439,539	64,695	16,269	15,924	587,532	116	96
1933	10,855	16,651	264,937	28,466	8,625	1,343	330,877	66	94
1934	7,096	17,665	335,623	16,499	10,965	10,707	398,555	79	87
1935	122,473	17,266	627,040	35,990	22,305	11,710	836,784	166	129
1936	256,970	15,766	743,668	25,704	24,307	7,446	1,073,861	213	158
1937	23,696	4,929	254,792	41,231	25,414	1,320	351,382	70	104
1938	4,787	4,963	266,076	33,490	16,574	934	326,824	65	88
Average	62,836	25,360	401,532	42,420	21,882	7,411	561,441	....	....
Percentage	11.2	4.5	71.5	7.6	3.9	1.3	.....	....	....

[1]Includes the catches from large-mesh gill nets, deep trap nets, hooks, and spearing as well as catches for which records of gear were not available.

Table 3. Catch of yellow perch per unit fishing effort of five gears over the period, 1929-1938, and the annual fluctuations in the abundance of yellow perch expressed as percentages of the 1929-1934 average

Year	Catch in pounds per unit effort in gear					General abundance
	Small-mesh gill net	Pound net	Shallow trap net	Fyke net	Seine	
1929	45.71	6.46	17.75	5.61	30.02	110
1930	14.61	7.37	17.91	10.19	22.02	110
1931	9.74	6.72	16.54	10.51	22.34	98
1932	15.59	6.63	19.28	12.22	19.87	121
1933	8.66	2.93	11.50	7.04	14.95	71
1934	7.85	4.16	14.70	6.08	26.96	90
1935	12.20	3.83	23.98	12.04	51.60	125
1936	15.70	5.36	26.20	6.59	41.64	133
1937	4.99	3.38	10.68	9.32	43.52	66
1938	3.78	3.56	11.91	7.06	34.06	73
Average, 1929-1934	17.03	5.71	16.28	8.61	22.69	100

The low production of yellow perch in Saginaw Bay since 1916 cannot be attributed to a relaxation of fishing effort. On the contrary, it is conceded generally that the fishing intensity of recent years is far greater than it was in the earlier years of the fishery. Consequently, the low production of the present-day fishery must be recognized as the result of a reduction in the density of the population. Although a detailed consideration of the causes of the depletion of the yellow perch population of Saginaw Bay does not come within the scope of this paper, it can be stated safely that over-fishing probably played a dominant role. Pollution also may have been an important factor.

The detailed records of daily fishing activities that must be submitted at the end of each month by every commercial fisherman licensed to operate in the State of Michigan waters of the Great Lakes make possible the presentation of data for the years, 1929-1938, relative to the composition of the catch of yellow perch according to the gear of capture and to the annual fluctuations in production, fishing intensity, and the abundance of fish on the grounds (Tables 2 and 3). From Table 2 it may be seen that the shallow trap net now accounts for the greater portion of the catch. This gear not only took 71.5 per cent of the total catch in the 10 years, but computations of percentages for the individual years reveal that in 3 years (1933, 1934, and 1938) trap nets took more than 80 per cent of the total, and that in no year did they take less than 61 per cent. The remaining gears in the order of their importance for the production of perch were as follows: Small-mesh gill nets, fyke nets, pound nets, and seines. However, the relative importance of these minor gears varied considerably from year to year. For example, the percentage of the total catch produced by small-mesh gill nets ranged from 23.9 per cent in 1936 to 1.5 per cent in 1938. The annual variations in the percentage of perch taken in pound nets, fyke nets, and seines were somewhat less extensive.

The different gears showed only fair agreement with respect to the annual fluctuations in the quantity of yellow perch taken per unit fishing effort.[2] As illustrations, the lifts of pound nets were not benefited by the increase in general abundance that occurred in 1935, and the catches of both fyke nets and seines failed to suffer from the great decline in abundance in 1937. These disagreements are not surprising since the production of yellow perch in gears other than the shallow trap net is normally so small that considerable random variation in the catch per unit of effort may be expected.

Total production, fishing intensity, and the abundance[3] of fish on the grounds were subject to considerable annual fluctuation (Tables 2 and 3; Fig. 1). Of the three, production was the most variable. The maximum production was more than three times the minimum whereas the maxima of the intensity and abundance percentages were about twice the minima. The greater range of variation of production arises from the circumstance that the simultaneous occurrence of maxima of both fishing intensity and abundance in 1936 led to an exceptionally high yield in that year. Fishing intensity was above average in the year of lowest abundance (1937) and abundance was above average in the year of lowest fishing intensity (1929). In 1938, however, both abundance and fishing intensity were sufficient below average to carry production to the low level of 65 per cent of average.

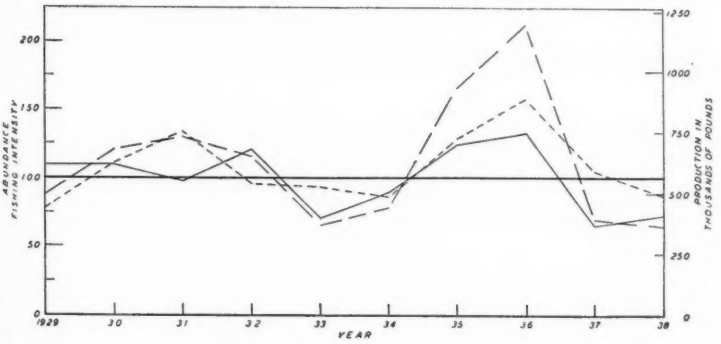

Figure 1.—Annual fluctuations in the abundance ———, and production — — — of yellow perch, and in the intensity of the fishery for perch - - - in Saginaw Bay, expressed as percentages of the 1929-1934 average.

[2]The units of effort for the various gears are as follows: Small-mesh gill nets—the lift of 1,000 linear feet; pound nets, shallow trap nets, and fyke nets—the lift of one net; seines—one haul of a 100-rod seine.

[3]The method of computing general abundance was outlined by Hile (1937). The fishing intensity in a particular year is the catch that would be expected from the amount of gear fished if abundance were exactly normal, expressed as a percentage of the mean of the "expected" catches in the years, 1929-1934. This 6-year period has been taken tentatively as the "normal" or "period of reference" for the study of fluctuations in the modern commercial fisheries of the Great Lakes waters of the State of Michigan.

Body-Scale Relationship and the Calculation of Growth

The method employed in this study for the calculation of individual growth histories of Saginaw Bay yellow perch from scale measurements was determined by a study of "key" or selected scales from 512 individuals, collected at various dates from April to November in the years 1921, 1925-1927, 1930, and 1934. The relationship between body length and the measurements of the anterior interradial spaces of these key scales[4] may be found in Table 4. (See also Fig. 2.)

The values of the body-scale ratio (L/Sc) in Table 4 demonstrate that among the smaller yellow perch the relative size of the scale increases with increase in the length of the fish. This increase in the relative size of the scale comes to an end, however, at a body length of about 90 millimeters, beyond which point the body-scale ratio remains nearly constant. The limited extent of the variations in the relative size of the scales of these larger fish is brought out in Figure 2 by the closeness with which the line, $L = 1.24\ Sc$, (1.24 is the grand average value of the body-scale ratio of perch more than 90 millimeters long) fits the empirical averages of body lengths (L) and scale measurements (Sc). The most notable discrepancies occur beyond the length of 200 millimeters. Even these discrepancies are not great and the numerical representation of the larger fish was relatively weak. It appears valid, therefore, to assume that the body-scale ratio is constant at all lengths beyond 90 millimeters.

Direct-proportion computations may be used for the calculation of lengths that are greater than the length at which the body-scale ratio

Table 4.—Relationship between body length (L) *and the anterior interradial measurement* (Sc) *of "key" or selected scales of Saginaw Bay yellow perch*

Number of fish	Standard length (millimeters)	Scale length (millimeters X 40.7)	Average L/Sc ratio
20	48.4	26.6	1.82
98	55.4	31.8	1.74
83	64.2	40.9	1.57
20	73.9	52.4	1.41
24	84.9	63.8	1.33
27	94.1	74.0	1.27
18	104.3	82.4	1.27
13	114.4	92.9	1.23
7	123.6	101.9	1.21
16	134.4	107.7	1.25
27	145.9	117.1	1.25
27	154.2	122.0	1.26
41	164.7	133.6	1.23
30	175.0	142.0	1.23
22	185.5	148.8	1.25
12	193.3	153.4	1.26
12	204.1	170.4	1.20
8	213.2	180.2	1.18
3	222.3	181.3	1.23
3	233.7	198.3	1.18
1	265.0	198.0	1.34

[4]Details concerning the exact location of the key scales and methods of measurement are given by Jobes (MS.).

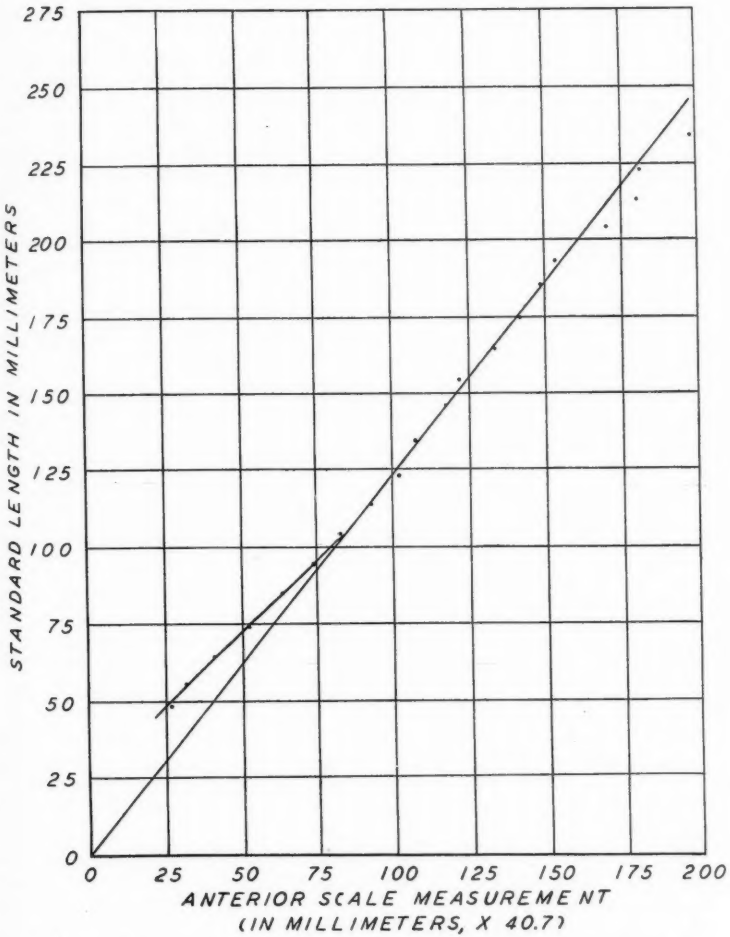

Figure 2.—Relationship between the standard length of Saginaw Bay yellow perch and the measurements of (magnified) key scales

becomes constant. Calculated lengths below that point must be corrected to compensate for the disproportionate growth of body and scale. Although these corrections can be read directly from the curve, it has been found more convenient to prepare Table 5 which lists the "correction" to be added to each direct-proportion calculated length.[5] The table contains corrections for direct-proportion calculated lengths as high as 101 millimeters, although a constant body-scale ratio was assumed for all lengths beyond 90 millimeters. The necessity for corrections of lengths over the interval, 90-101 millimeters, arises from the fact that the natural continuation of the body-scale curve that was drawn free-hand for the smaller fish meets the line, $L = 1.24\ Sc$, at the length of approximately 103 millimeters rather than at 90 millimeters. The corrections in the interval, 90-101 millimeters, do not exceed 3 millimeters and are only 1 or 2 millimeters at most lengths.

All first-year calculated lengths fell within the range for which a correction was necessary. Part of the calculated lengths for the second year but none for later years needed to be corrected.

Table 5.—Correction (in millimeters) to be added to direct-proportion calculated lengths to compensate for the disproportionate growth of body and scale in small Saginaw Bay yellow perch

Interval of direct-proportion calculated length (millimeters)	"Correction" to be added (millimeters)	Interval of direct-proportion calculated length (millimeters)	"Correction" to be added (millimeters)
38-40	16	68-72	8
41-45	15	73-75	7
46-49	14	76-79	6
50-53	13	80-83	5
54-58	12	84-88	4
59-60	11	89-91	3
61-64	10	92-95	2
65-67	9	96-101	1

Age Composition and Length Frequencies

The age composition of each year's sample and of the combined collections of Saginaw Bay yellow perch is given in Table 6. The 1929 collection was characterized by the strong dominance of age-group IV (72.0 per cent of the entire sample). Age-group III was dominant in 1930 (49.4 per cent) but age-group IV was more than half as strong (25.1 per cent) and age-group V also was well represented (19.3 per cent). In the combined collections age-groups III and IV were almost exactly of equal abundance. Of the remaining four age groups only the V group contained a large number of fish. The scarcity of II-group perch in the collections is traceable in part to the selective action of the gear, whose meshes were too large to retain the smaller perch.

[5]Jobes (MS.) gave a discussion of the use of the empirical body-scale curve for the determination of corrected calculated lengths and explained the procedure by which a table of the type of Table 5 is prepared.

Biological segregation according to maturity also may have contributed to the scarcity of perch of the younger age groups. The samples were taken almost exclusively from the spawning run which includes only the mature (older) perch. However, the small numbers of perch of age-groups VI and VII reflect a scarcity of older fish on the fishing grounds.

Although the data of Table 6 are not adequate for a detailed analysis of the relative strengths of the year classes represented, it does appear valid to conclude that the 1925 year class was one of greater than average strength. The chief argument for this conclusion lies in the strong dominance of the 1925 year class as the 1929 IV group. In this year's sample age-group IV was 5.7 times as abundant as age-group III and 6.6 times as abundant as age-group V. The same year

Table 6.—Age and year-class composition of collections of yellow perch from Saginaw Bay

Year of capture	Item	Age group					
		II	III	IV	V	VI	VII
1929	Number of fish	7	30	172	26	2	2
	Percentage of sample	2.9	12.6	72.0	10.9	0.8	0.8
	Year class	1927	1926	1925	1924	1923	1922
1930	Number of fish	18	287	146	112	15	3
	Percentage of sample	3.1	49.4	25.1	19.3	2.6	0.5
	Year class	1928	1927	1926	1925	1924	1923
1929 and 1930	Number of fish	25	317	318	138	17	5
	Percentage of sample	3.0	38.7	38.8	16.8	2.1	0.6

class, as the 1930 V-group, was only slightly less abundant than fish a year younger. As a possible alternate explanation of the great abundance of the 1925 year class in the collections it might be held that the 1926 year class was exceptionally weak. With either interpretation the data for Saginaw Bay provide a striking contrast with Lake Erie, where 1926 saw the production of a phenomenally rich year class not only of yellow perch but of several other species as well (Van Oosten, 1938).

Preliminary tabulations failed to reveal significant differences in the length-frequency distributions of perch of the same age and sex in the two years' collections. Accordingly the length frequencies of Table 7 have been based on a combination of the 1929 and 1930 data. It may be seen readily that the extensive overlap of the frequency distributions of the successive age groups makes the length of an individual a relatively poor index of its age. Over intervals in which fish are abundant an individual fish of a particular length may belong to any one of two or three (usually three) age groups. The length-frequency distributions are characterized further by the tendency for the modal lengths of the females to be greater than those of males of corresponding age. This situation is reflected in the higher average

Table 7.—Length-frequency distribution of Saginaw Bay yellow perch according to age and sex. The 1929 and 1930 collections have been combined. The legal length of 187 millimeters corresponds to the total length of 8½ inches

Standard length interval (millimeters)	II		III		IV		V		VI		VII		II-VII		
	M[1]	F[2]	M	F	M	F	M	F	M	F	M	F	M	F	Total[3]
120-124	1	..	..	..	..	..	..	..	..	..	..	..	1	..	3
125-129	3	..	..	..	..	..	..	..	..	..	..	..	3	..	3
130-134	2	..	..	..	..	..	..	..	..	..	..	..	2	..	2
135-139	..	1	..	..	..	..	..	..	..	..	..	..	..	1	2
140-144	..	1	2	..	..	..	..	..	..	..	..	..	2	1	5
145-149	2	3	..	1	..	..	..	..	..	..	..	..	2	4	7
150-154	..	..	2	..	..	..	..	..	..	..	..	..	2	..	2
155-159	..	1	3	2	2	..	..	..	..	..	..	..	5	3	10
160-164	..	2	7	8	1	..	..	..	..	..	..	..	8	10	19
165-169	1	..	11	5	1	..	..	..	..	..	..	..	13	5	18
170-174	..	3	4	17	1	..	..	..	..	..	..	..	5	20	26
175-179	..	..	7	22	1	2	..	..	..	..	..	..	8	24	32
180-184	..	..	10	28	3	3	..	..	..	..	..	..	13	31	44
185-189	..	..	7	43	5	3	..	..	..	..	..	..	12	46	58
190-194	..	..	3	38	11	7	1	1	..	..	..	..	15	46	61
195-199	..	..	1	21	11	11	1	1	..	..	..	..	13	33	46
200-204	..	..	..	19	8	26	1	..	..	..	..	..	9	45	56
205-209	..	..	3	12	4	17	1	4	..	..	..	..	8	33	43
210-214	..	..	..	12	13	27	2	3	..	..	..	..	15	42	57
215-219	..	..	..	12	7	26	1	6	..	..	..	..	8	44	52
220-224	..	..	2	5	6	27	..	6	1	..	..	..	9	38	47
225-229	..	..	..	..	3	29	10	6	..	..	..	..	13	35	48
230-234	..	..	..	..	4	20	8	13	..	1	..	..	12	34	48
235-239	..	..	..	1	5	11	2	8	..	..	..	..	7	20	27
240-244	..	..	..	..	1	12	3	10	..	2	..	..	4	24	29
245-249	..	..	..	..	..	6	4	7	..	..	..	..	4	13	17
250-254	..	..	..	..	..	1	2	13	1	3	..	..	3	17	20
255-259	..	..	..	..	..	1	1	6	1	..	..	..	2	7	9
260-264	..	..	..	..	..	..	1	6	..	4	..	1	1	11	12
265-269	..	..	..	..	..	..	..	2	1	..	..	1	1	3	4
270-274	..	..	..	..	..	..	..	2	..	..	..	..	..	2	2
275-279	..	..	..	..	..	..	..	2	..	3	..	1	..	6	6
280-284	..	..	..	..	..	..	1	1	..	..	1	..	2	1	3
285-289	..	..	..	..	..	..	..	1	..	..	1	..	1	1	2
Number of fish	9	11	62	246	87	229	39	98	4	13	2	3	203	600	820
Average standa d length	136	156	176	191	205	218	232	240	259	258	284	269	200	211	207
Percentage illegal (less than 187 millimeters)	100.0	100.0	83.9	46.3	13.8	2.6	0.0	0.0	0.0	0.0	0.0	0.0	36.0	21.8	26.1

[1]M—Male. [2]F—Female. [3]Includes 17 fish for which sex records were lacking.

lengths of the females in all age groups but the poorly represented VII group.

The percentage of illegal-sized perch (less than 8½ inches, total length) in each age group has been given at the bottom of Table 7. All II-group perch were undersized near the beginning of the third year of life. However, the presence of legal-sized fish in age-group III suggests the possibility that a few II-group yellow perch may attain legal size during the third growing season. Most of the III-group males (83.9 per cent) were below legal length but only 46.3 per cent of the females fell below 8½ inches. Continued growth during the fourth year of life doubtless brings about a large increase in the percentage of legal-sized fish in age-group III. This belief is supported by the observation that a high percentage of IV-group perch was above legal length at the beginning of the fifth growing season. No undersized perch occurred in age-groups V, VI, or VII. The percentages of undersized perch for all age groups combined were 36.0 per cent for the males, 21.8 per cent for the females, and 26.1 per cent for the sexes combined.

The data on the age composition and the length distribution of the yellow perch of the samples from Saginaw Bay reveal that the commercial fishery is supported almost entirely by age-groups III, IV, and V. The inclusion of age-group III is justified by the fact that the bulk of the commercial catch is produced in late season at which time III-group fish have completed most or all of their fourth-year growth. The four months, September to December, accounted for 77 per cent of the total 1936-1938 production of perch. The percentage was 45 for October alone.

Growth in Length and Weight

The length and weight at capture and the calculated growth history of each age group in each year's collection of Saginaw Bay yellow perch are given for the males in Table 8 and for the females in Table 9. A separation of data has been made also according to year class. At the bottoms of the tables may be found the grand average lengths at the end of each year of life and the growth increments during each year of life. The data for the II groups were not employed in the computation of the grand averages. The small numerical representation of yellow perch of this age together with their high calculated lengths (particularly in the 1930 samples) suggested that the gear employed for the collection of the samples may have taken only the larger II-group fish. Gear selection may have affected somewhat the reliability of the III groups also; however, the extremely strong representation of this age group in the 1930 collection indicates that the selection was not very severe. Consequently the data for all III groups were employed in the calculation of grand averages.

Most of the discrepancies between corresponding calculated lengths of different age groups of males can be attributed to the small num-

Table 8.—Average length and weight at capture of male yellow perch from Saginaw Bay and the average calculated length attained by the age groups (and year classes) at the end of each year of life

Year class	Year of capture	Age group	Number of fish	Weight (ounces)	Total length (inches)	Weight (grams)	Standard length (mm.)	Calculated standard length in millimeters at end of year						
								1	2	3	4	5	6	7
1922	1929	VII	2	12.75	12.8	361	284	62	114	160	209	246	268	284
1924	1929	V	4	8.12	10.7	230	235	64	104	156	204	235	..	..
	1930	VI	4	11.19	11.2	317	250	69	104	138	178	220	250	..
1925	1929	IV	46	5.39	9.2	153	203	62	106	161	202	..	..	..
	1930	V	35	8.30	10.6	235	232	63	104	161	205	232	..	..
1926	1929	III	6	4.47	8.8	127	194	70	136	192	..	..	..	..
	1930	IV	41	6.04	9.5	171	208	68	118	169	207	..	..	..
1927	1929	II[1]	2	1.20	5.8	34	126	69	126	..	..	..	..	..
	1930	III	56	3.25	8.1	92	174	65	123	172	..	..	..	..
1928	1930	II[1]	7	1.79	6.4	51	139	84	139	..	..	..	..	..
Grand average calculated length[2]								65	114	166	204	232	259	275
Grand average calculated increment of length[2]								65	49	52	38	28	27	16

[1]Age group not employed in the computation of grand averages.
[2]Grand average calculated lengths at the end of the sixth and seventh years of life were obtained by the successive addition of the grand average increments of growth in the sixth and seventh years to the grand average calculated length at the end of the fifth year.

Table 9.—Average length and weight at capture of female yellow perch from Saginaw Bay and the average calculated length attained by the age groups (and year classes) at the end of each year of life

Year class	Year of capture	Age group	Number of fish	Weight (ounces)	Total length (inches)	Weight (grams)	Standard length (mm.)	Calculated standard length in millimeter at end of year						
								1	2	3	4	5	6	7
1923	1929	VI	2	10.50	11.1	298	247	64	103	143	188	220	242	..
	1930	VII	3	12.83	12.1	364	269	63	101	141	179	216	246	269
1924	1929	V	21	8.45	10.6	240	234	65	109	153	193	232	..	..
	1930	VI	11	11.48	11.7	325	260	60	96	140	180	222	260	..
1925	1929	IV	124	[1]7.12	10.0	202	219	64	108	166	218	..	..	..
	1930	V	77	[1]9.27	10.8	263	241	62	105	160	208	241	..	..
1926	1929	III	15	4.10	8.4	116	185	67	119	182	..	..	..	..
	1930	IV	105	6.27	9.9	178	217	65	114	171	214	..	..	..
1927	1930	III	231	4.23	8.7	120	191	66	126	187	..	..	..	..
1928	1930	II[2]	11	2.43	7.2	69	156	82	153	..	..	..	..	..
Grand average calculated length[3]								65	116	174	211	236	270	293
Grand average calculated increment of length[3]								65	51	58	37	25	34	23

[1]The average weight is based on one less fish than employed to obtain the average lengths.
[2]Age group not employed in the computation of grand average.
[3]Grand average calculated lengths at the end of the sixth and seventh years of life were obtained by the successive addition of the grand average increments of growth in the sixth and seventh years to the grand average calculated length at the end of the fifth year.

STANDARD LENGTH IN MILLIMETERS

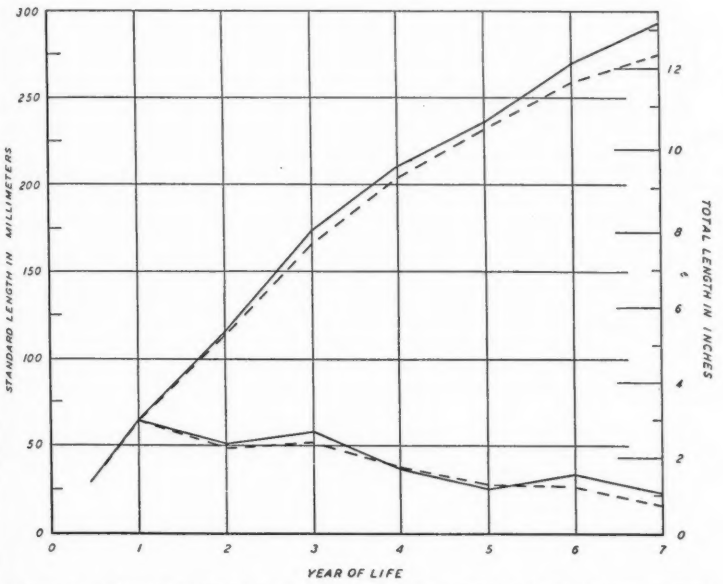

Figure 3.—Calculated lengths at the end of each year of life (upper curves) and increments of growth in length in each year of life (lower curves) of Saginaw Bay yellow perch, males — — —, females ————.

bers of specimens in the different age groups. There was almost perfect agreement between the growth histories of the two age groups of the only year class (year class of 1925) that was well represented in both years' collections. The data for the females, on the other hand, appear to contain discrepancies in calculated growth histories, correlated with age. The younger age groups of the 1924, 1925, and 1926 year classes consistently had higher calculated lengths than older fish of the same year class. A complete discussion of possible factors contributing to this type of discrepancies in calculated growth was presented by Jobes (MS.) and hence need not be included here. It should be pointed out, nevertheless, that errors originating in the method of calculating growth do not seem to be a factor.

The general growth curves of both sexes contain inflections. (See Fig. 3.) The greatest growth in length occurred in the first year of life. Growth declined in the second year but improved in the third. Beyond the third year the annual increments of length of the males decreased continually. The growth increments of the females decreased from the third to the sixth year of life, increased in the sixth

[1] Grand average calculated lengths at the end of the sixth and seventh years of life were obtained by the successive addition of the grand average increments of growth in the sixth and seventh years to the grand average calculated length at the end of the fifth year.

year and decreased again in the seventh year. It is unlikely that the increase in the growth increment that occurred in the sixth year of life is typical for females of the Saginaw Bay yellow perch.

The legal length of 8½ inches, total length (187 millimeters, standard length), falls between the third-year and fourth-year calculated lengths of both sexes. On the average, females attained the legal length earlier in the fourth growing season than did the males.

Table 10 contains data on general growth in weight, that correspond exactly to the general curves of growth in length; that is, the weight corresponding to each grand average calculated length has been computed from the length-weight equation given on page ???. The resulting curves of growth in weight (both in grams and ounces) are presented in Figure 4. The positions of the average weights of the age groups at capture, with the data for corresponding age groups of the two years' collections combined, are shown by small triangles for the males and dots for the females. It may be seen that the empirical averages of the age groups of both sexes fall rather closely along their

Table 10.—Calculated weights in grams corresponding to the grand average calculated lengths of Saginaw Bay yellow perch at the end of each year of life, and the annual increments of growth in weight

Sex	Item	Year of life						
		1	2	3	4	5	6	7
Male	Calculated weight	4	25	82	156	233	328	395
	Increment of weight	4	21	57	74	77	95	67
Female	Calculated weight	4	27	95	173	245	373	482
	Increment of weight	4	23	68	78	72	128	109

respective theoretical curves. Since the average length of VII-group males at capture exceeded the calculated length at the end of the seventh year the weight of this age group at capture cannot be shown in Figure 4.

The annual increments of growth in weight of males increased continuously during the first 6 years of life and decreased in the seventh. The increase in the annual increments of weight of females was interrupted by a small decline in the fifth year. The growth of the females improved notably in the sixth year but fell away in the seventh. The Saginaw Bay yellow perch becomes subject to capture in the commercial fishery just as it is entering on the period of most rapid growth in weight. In fact, the greatest growth in weight of both sexes occurred in the sixth year of life, approximately two years subsequent to the attainment of legal length.

Relationship between Total Length and Standard Length

Since many scientific papers list only standard lengths, whereas anglers and conservationists employ total lengths, a knowledge of the relationship between the two measurements is of practical value.

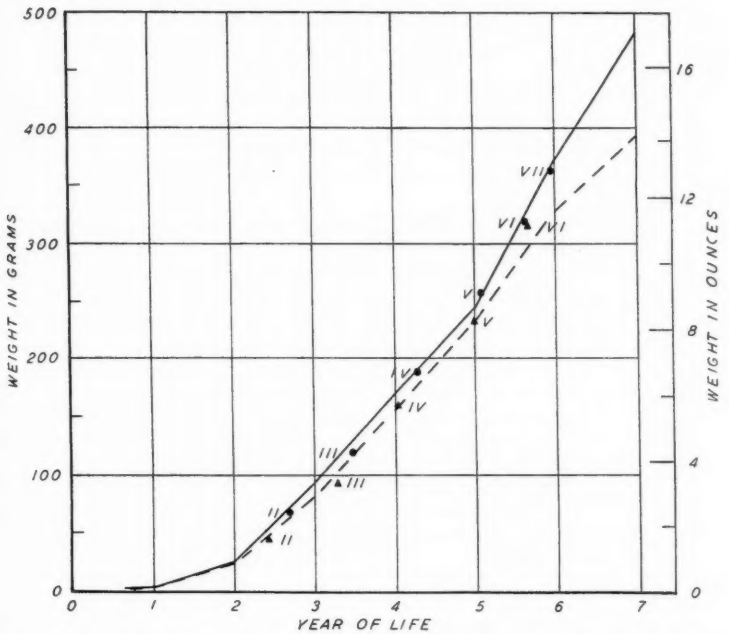

Figure 4.—Calculated growth in weight of Saginaw Bay yellow perch, males — — —, females ————. The weights of the age groups at capture are shown by small triangles for the males and dots for the females.

Table 11 contains the factors for conversions between total length and standard length, both with and without change of units of measurement. These factors vary according to the size of the fish, since the relative length of the tail tends to decrease with increase in the length of the fish. A similar change in the relative size of the caudal fin was observed by Van Oosten (1938) for the Lake Erie sheepshead and for the Lake Huron whitefish (Van Oosten, 1939). Preliminary compilations revealed a tendency for the tails of female yellow perch to be relatively shorter than those of males. This sex difference was not sufficiently great, however, to make necessary the determination of conversion factors for the sexes separately.

Length-Weight Relationship and Condition

The data on the length-weight relationship of the Saginaw Bay perch (Table 12, Fig. 5) have been based on 1,483 fish captured in the

Table 11.—Factors for the conversion of total (T. L.) and standard (S. L.) lengths of the Saginaw Bay yellow perch

Standard length (millimeters)	Number of fish	Conversion factors			
		T.L. to S.L. (No change of unit)	S.L. to T.L. (No change of unit)	S.L. (millimeters) to T.L. (inches)	T.L. (inches) to S.L. (millimeters)
Under 175	248	0.849	1.177	0.0464	21.57
175—239	996	0.866	1.155	0.0455	22.00
Over 239	167	0.877	1.141	0.0449	22.27

autumn of 1928, the spring and autumn of 1929, and the springs of 1930 and 1934. Figure 5 has been so arranged as to permit ready conversions from standard lengths in millimeters and weights in grams to total lengths in inches and weights in ounces.

The dots in Figure 5 represent the empirical averages of length and weight; the smooth curve is the graph of the equation,

$$W = 0.9826 \times 10^{-5} L^{3.1174},$$

which was derived by fitting a straight line to the logarithms of the average lengths and weights[6] in the length interval, 140-264 millimeters. In the logarithmic form the equation may be expressed as,

$$\log W = -5.00754425 + 3.1174 \log L.$$

In both equations W = weight in grams and L = length in millimeters. The value of the exponent, 3.1174, shows that the weight of Saginaw Bay yellow perch increases somewhat more rapidly than the cube of the length.

Table 12.—Relationship between the length and the weight of Saginaw Bay yellow perch. (See text for method of determining the calculated weights.)

Number of fish	Standard length (millimeters)	Weight (grams)		Total length (inches)	Weight (ounces)
		Empirical	Calculated		
8	125	32	34	5.8	1.1
19	135	42	43	6.3	1.5
35	145	52	54	6.7	1.8
48	154	68	65	7.1	2.4
96	165	82	80	7.7	2.9
104	175	97	97	8.0	3.4
169	185	111	115	8.4	3.9
198	194	134	133	8.8	4.7
188	204	155	156	9.3	5.5
178	214	186	181	9.7	6.6
162	224	215	208	10.2	7.6
111	233	235	236	10.6	8.3
69	244	269	272	11.0	9.5
41	253	300	305	11.4	10.6
29	263	351	344	11.8	12.4
13	275	360	395	12.3	12.7
10	285	402	442	12.8	14.2
1	295	502	492	13.2	17.7
1	338	462	752	15.2	16.3
3	351	508	846	15.8	17.9

[6]Originally the average lengths and weights were determined by 5-millimeter rather than centimeter length intervals, and it was from these 5-millimeter averages that the constants for the equation were determined.

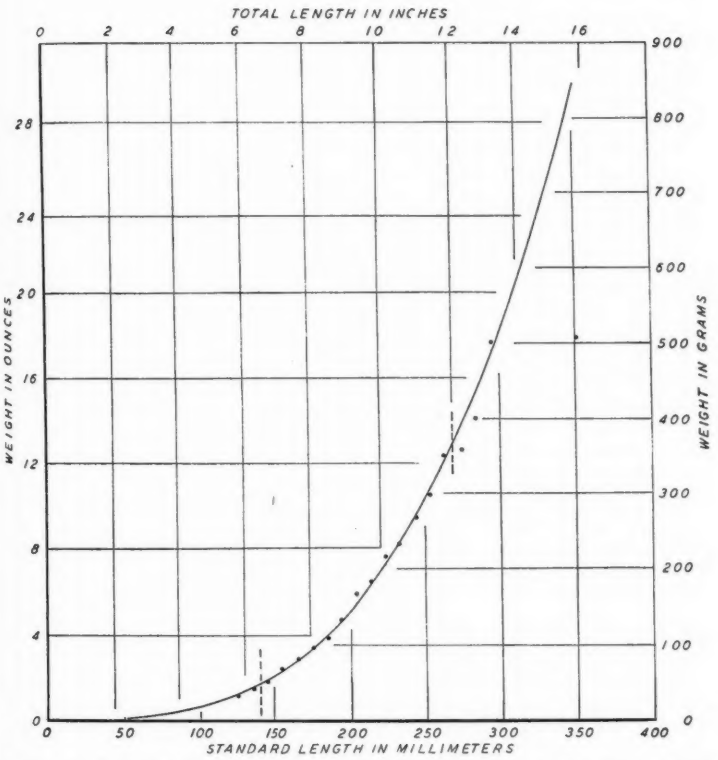

Figure 5.—Length-weight relationship of the Saginaw Bay yellow perch (sexes combined). The broken vertical lines indicate the limits of the length range over which the length-weight equation was fitted.

Comparisons of the empirical weights with those calculated from the length-weight equation (Table 12) reveal good agreement over the length interval for which the equation was fitted. The greatest discrepancy was only 7 grams (at 224 and 263 millimeters) and the mean of the absolute values of the discrepancies was only 3.2 grams. The agreement between calculated and empirical weights was close also at 125 and 135 millimeters. At the greater lengths (beyond 263 millimeters) the calculated and empirical weights disagreed radically. To some extent these discrepancies may depend on the small number of specimens. The data provide some evidence, however, that old

Table 13.—Average coefficient of condition (K) *for the age groups of Saginaw Bay yellow perch. The sexes are combined*

Number of fish	Age group	*K*
25	II	1.75
317	III	1.72
317	IV	1.83
137	V	1.84
17	VI	1.92
5	VII	1.74

perch may tend to be lighter than would be expected on the assumed theoretical grounds.

The Saginaw Bay yellow perch weighs approximately 4 ounces when it attains the legal length of 8½ inches.

The coefficient of condition[7], *K*, was computed for every fish whose age was determnied. (Weights were lacking for 2 of the 820 specimens.) The variation of condition with age is indicated in Table 13.

The grand average coefficient of condition was 1.79 for each sex. This value indicates that the Saginaw Bay yellow perch has a more slender body form than the Lake Erie yellow perch. The average *K* for the perch in Lake Erie was found to be 1.91 (Jobes, MS.).

Table 14.—Number of males and females in each age group of Saginaw Bay yellow perch, and the sex ratio expressed as number of females per 100 males

Age group	Number of males	Number of females	Females per 100 males
II	9	11	122
III	62	246	397
IV	87	229	263
V	39	98	251
VI	4	13	325
VII	2	3	150
II-VII	203	600	296

Maturity and Sex Ratio

Of the 820 perch whose ages were determined, 788 or 96 per cent were mature. A high percentage of mature individuals is to be expected in collections that are composed chiefly of spawning-run samples.

Sex data were available for 803 specimens. The distribution of the sexes according to age (1929 and 1930 collections combined) may be seen in Table 14.

Females predominated in every age group. For all age groups combined the females outnumbered the males in the ratio, 296 :100. The variations of the sex ratio among the age groups failed to exhibit a distinct trend.

It should be mentioned that data on the sex ratio obtained from spawning-run collections may not be descriptive of the true sex ratio of the general population. Commonly the sex ratio shifts during the spawning season from a predominance of males near the beginning of the period to a predominance of females toward the close. Consequent-

[7] $K = \frac{W \times 10^5}{L^3}$, where W = weight in grams and L = length in millimeters.

ly the sex ratios of spawning-run samples vary according to the time of collection in the spawning season. The great relative abundance of females in the perch collections from Saginaw Bay lends support to the belief that females may predominate in the population toward the close of the spawning run since most of the samples were taken late in the spawning season. (Only a few samples were collected subsequent to the spawning period.)

Summary

1. Although the yellow perch grounds of Saginaw Bay continue to be the most productive in the State of Michigan waters of the Great Lakes, the average annual yield over the period, 1917-1938, has been only 28 per cent of the earlier (1891-1916) normal.

2. The shallow trap net accounts for the bulk of the catch of Saginaw Bay yellow perch in the modern fishery (71.5 per cent of the 1929-1938 production).

3. Detailed statistical analyses for the 10 years, 1929-1938, revealed that production, the abundance of perch on the grounds, and the intensity of the fishery for perch are subject to large annual fluctuations. The maximum annual production of the period was roughly three times the minimum. The maxima of abundance and fishing intensity were about twice the minima.

4. The study of the growth of the Saginaw Bay yellow perch was based on the determination of the age and the calculation of growth from the examination and measurement of the scales of 820 individuals captured in pound nets in the spring and early summer fishing seasons of 1929 and 1930. The numbers of specimens employed in other phases of the study were: Body-scale relationship—512 fish captured at various dates from April to November in the years, 1921, 1925-1927, 1930, and 1934; relationship between total length and standard length —1,411 perch collected in 1928-1930 and 1934; length-weight relationship—1,483 individuals taken in 1928-1930 and 1934.

5. The constancy of the body-scale ratio among the larger perch makes the use of the direct-proportion method of calculating individual growth histories valid at all calculated lengths above 101 millimeters. Calculated lengths of 101 millimeters or less were corrected (from an empirical curve of the body-scale relationship) to compensate for the disproportionate growth of body and scale in small fish.

6. The modal lengths of the length-frequency distributions of females tended to be greater than those of males of corresponding age. The length frequencies of the successive age groups of both sexes exhibited extensive overlap. In the complete sample (age groups and sexes combined) 26.1 per cent were below the legal length of 8½ inches.

7. The 1929 collection was dominated by the 1925 year class as age-group IV (72.0 per cent of the total) and the 1930 collection was dominated by the 1927 year class as age-group III (49.4 per cent). Age-group III and IV were equally represented in the combined 1929-1930

collections (approximately 39 per cent each). The 1925 year class appears to have been unusually strong.

8. Females grew more rapidly than did the males. The greatest growth in length of both sexes occurred in the first year of life. The annual growth increments decreased in the second year and increased in the third. Beyond the third year of life the annual length increments decreased continuously for the males and irregularly for the females. Both sexes attained the legal length of 8½ inches during the fourth year of life.

9. The greatest annual increment of weight of both sexes occurred in the sixth year of life. The annual increments of growth in weight increased continuously during the first 6 years of life of the males and during the first 4 years of life of the females. The Saginaw Bay yellow perch becomes subject to capture in the commercial fishery just as it is entering the period of most rapid growth in weight.

10. The ratio of standard length to total length increased with increase in the length of the fish.

11. Over the length interval, 120-265 millimeters, the length-weight relationship was described satisfactorily by the equation,

$$W = 0.9826 \times 10^{-5} L^{3.1174},$$

where W = weight in grams and L = length in millimeters. At most lengths greater than 265 millimeters the actual weights were smaller than those computed from the equation.

12. The average value of the coefficient of condition, K, of the age groups varied from 1.72 to 1.92. For all age groups combined the average K was 1.79.

13. Ninety-six per cent of the yellow perch whose ages were determined were mature. Females outnumbered the males in the ratio, 296:100, and were in the majority in every age group.

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RESTORATION OF THE ATLANTIC SALMON IN NEW ENGLAND

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ABSTRACT

The Atlantic salmon, *Salmo salar* Linnaeus, has been practically exterminated from New England waters as a result of heavy fishing, deforestation, pollution, and the construction of dams or other obstructions to migrations. In recent years, conditions on some of the streams have been improved due to the abatement of many of these harmful conditions, and it now seems probable that an adequate restoration program would prove successful. A comprehensive program is proposed which calls for the following: A detailed survey of all potential salmon streams to determine their present condition; the selection of the best stream or streams for experimental work; the formulation of State laws to provide control of all fishing operations; a program of scientific observation and analysis including annual enumeration of the spawning stock; the determination of the numbers and mortality of naturally-spawned young in different tributaries and the mortality of hatchery-produced young released at different ages and at different seasons, with the ultimate object of determining the optimum size of the spawning run for each main tributary.

Atlantic salmon (*Salmo salar* Linnaeus) once were abundant in nearly all of the larger New England rivers, as well as in numerous smaller streams. Today, there is a mere remnant of these runs in the Penobscot and Dennys Rivers, and in a few other streams in eastern Maine.

The destruction of the salmon runs was due to many factors. In the early years the salmon were fished heavily for food due to their easy accessibility while on their upstream migrations. At the same time, many small dams, usually built in the tributaries of the main rivers, served to cut off spawning grounds and rearing areas for the young. Other developments assisted in destroying salmon runs in the rivers not blocked by dams. During the settlement of New England, thousands of square miles of forest cover were removed with the result that the summer stream flow was reduced, temperatures were increased, freshets were intensified, and spawning beds were smothered by silt. Low water and high temperature were particularly serious when coupled with pollution arising from settlements along the rivers.

With the destruction of the salmon runs already threatened, New England entered a period of intensive industrial development. With increasing power requirements the construction of dams was extended to the large rivers and industrial wastes from tanneries, pulp mills and chemical works were added to the pollution from sewage and sawdust. The combination of unfavorable circumstances all but exterminated the salmon from New England. During the following years of con-

tinued adverse conditions, a few salmon were maintained in the streams of eastern Maine chiefly by means of imported Canadian eggs and artificial propagation at Federal and State hatcheries.

The situation eventually improved with the passing of the peak in agricultural and industrial development. The reversion to forest of thousands of acres of once cultivated farm land increased stream flow and lowered water temperatures. Rivers became less obstructed due to the decline in logging operations and the construction of fishways in many permanent dams. A decrease in sawmill wastes was coupled with some reduction of other pollution owing to a more enlightened public opinion. As the result of these various trends conditions apparently have improved on some of the rivers to the point where the restoration of salmon appears now to be practicable.

Aware of the growing interest in salmon, Mr. David Aylward, President of the National Wildlife Federation, requested the Fish and Wildlife Service for a report on the possibilities for salmon restoration, and for suggestions as to the best way in which it might be carried out. The authors, working in co-operation with Mr. George Stobie, Commissioner of Inland Fisheries for Maine, and with the advice of the commissioners of the other North Atlantic States and of Mr. Raymond Dow and other sportsmen, made a study of information available and submitted a report reviewing present conditions, together with recommendations as to a program for restoration work. The balance of this paper is a resumé of that report.

New England salmon already were on their way toward practical extinction long before the development of present methods of scientific fishery management. The various measures taken in the past to prevent their decline were ineffective by reason of worse environmental conditions than now prevail, in some of the rivers at least, and because of a lack of sufficient study of the various problems involved. This point is well brought home by a quotation from the late Dr. William C. Kendall (1935) in his monograph on the Atlantic salmon:

> "Notwithstanding the early fish cultural interest in the Atlantic salmon of New England, the continued fish cultural propagation of the fish at one Federal hatchery in Maine, and its potential commercial and angling value, no attempts to solve the many problems connected with the salmon have been made since those of Atkins over one-half century ago.
>
> ". . . . to me it seems not only extremely unfortunate, but fatal that so much reliance has been placed upon the applicability of the results of investigations on the other side of the ocean . . . . and so little done in the way of independent investigation. Canada has made and is still making some effort in that direction, but in the United States almost nothing has been done in the past, and absolutely nothing is being done now, with the consequence that her Atlantic salmon fishery is almost past history and the salmon is verging on extinction."

Some excellent work is being done in Canada to maintain the runs of Atlantic salmon, but the problem in New England is somewhat different. Canada is concerned with maintaining present runs whereas

the problem in New England is to reestablish salmon in rivers from which, with possibly one exception, they have been almost or completely exterminated. We believe that with the necessary and continued co-operation of the sportsmen, the commercial fishermen and the conservation officials of the several States, it is entirely within reason, judging from the size of the rivers and the potential spawning areas, to reestablish salmon runs of a magnitude beyond that visualized today by most sportsmen and fishermen. Such runs, under careful management, should supply sufficient salmon to meet the needs of the sportsmen, and in addition, should provide, with regulated fishing, a supplementary income of great value to the smaller fishing communities along the coast where the small-boat fishermen are finding it difficult or impossible to compete effectively with the mass production of fish from the offshore banks. However, if we are to accomplish the above results, it will be necessary to follow out a carefully conceived and extensive program. In our opinion, this program must include the following points.

The first point requires an adequate survey of all of the most promising New England rivers to discover:

1. The number and kind of obstructions to salmon migrations and the adequacy of fishways or other protective devices at these barriers.
2. The extent and degree of pollution and its limiting effect on migration and spawning.
3. The condition and extent of the spawning areas.
4. The suitability and capacity of the streams as rearing grounds for young salmon.

Some of this survey work is now being carried on by various States as rapidly as funds permit. Additional work under this program should be in cooperation with the several State biologists, and would supplement and coordinate their work.

The second point calls for the selection, on the basis of the survey, of one or more of the streams showing satisfactory spawning and nursery areas and a lack of impassable areas or pollution. Initial restoration efforts should be concentrated on the most favorable rivers for two reasons: (1) To provide an example to encourage the cleaning up of less favorable streams. (2) To establish self-perpetuating runs as early as possible to provide a source for additional eggs to be used in work on other streams. Furthermore, it is obvious that unless natural runs can be established in the best rivers, there is no use in wasting time and money on more polluted or more badly obstructed streams.

The third point involves the enactment of State laws prohibiting or placing adequate limitations on the capture of salmon on the test river or within a suitable distance from its mouth for a period of 10 years (or for such period as the survey data indicate to be necessary). Without such initial protection restoration has only a slight chance of success.

The fourth point requires the taking of an annual census of the

number of spawning adults. This census can be made by counting at a weir or fish ladder, or on the spawning grounds. In this way it will be possible to determine the returns from given amounts of stockings and from natural spawning.

The fifth point requires that a supply of eggs be obtained for hatching and planting each year for at least 5 years to establish runs in the principal portion of the river. The Fish and Wildlife Service hatchery at Craig Brook, Maine, has facilities for hatching and rearing the quantities required for this work. After runs once have been established, outside sources of eggs will be unnecessary as sufficient quantities should be available from the newly established runs to supply material for stocking in additional tributaries and later in other streams.

A hatching and rearing program will play an essential part in the general program to supply material for the primary stocking of streams. However, on the basis of present knowledge it does not appear practical to attempt to use hatcheries as the basis for maintaining regular large-scale runs. These runs must be maintained by natural spawning. However, it is possible that there may be some special situations where the combination of high recreational value and insufficient spawning grounds will make it desirable to maintain limited runs by means of artificial propagation alone.

The sixth point in the program calls for the marking of both "wild" and hatchery-reared parr and smolts to determine:

1. The relative value of different tributaries as spawning and nursery grounds.
2. The best age and season of the year to release hatchery stock.
3. The optimum size of the spawning run for each tributary.

The seventh point deals with the management of the test stream after it is opened to fishing. After 10 years or less should a sufficiently large run be established, the stream should be opened to controlled fishing. The amount of fishing permitted should be determined from the annual observations as to the abundance of fish. The catch permitted should be so determined as to leave an annual spawning run sufficient to build up and maintain a self-perpetuating stock at the most productive level. It is on this basis that the Service has rebuilt and maintained the tremendous salmon runs of Alaska.

The eighth point proposes a more thorough study of the practical possibility and of the possible advantages to be derived from the introduction of a more desirable West Coast species than the pink salmon previously tried in Maine waters. It is believed that the introduction of those species of Pacific salmon which furnish excellent sport fishing should be considered in a well-rounded program. It is worthy of note that the steelhead trout, the western counterpart of our Atlantic salmon, is most abundant in rivers highly populated with other species of salmon, and this abundance may well be a reflection of the fertilization of these waters by the dead salmon.

As we have pointed out in the preceding discussion, the most important problem today is to provide definite proof that extensive restoration of Atlantic salmon is feasible. If this restoration can be accomplished on one or two streams, ample support should be forthcoming for similar restoration on others. The initial program which should extend over a period of about 10 years, will require several biologists trained to conduct stream surveys, carry out tagging and marking experiments, and investigate other phases of the salmon's life-history. Funds for this program are not now available.

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Discussion

Mr. A. H. Underhill: The speaker said that the conditions which had contributed to the decline of salmon in New England had been alleviated in some cases. In what stream has that occurred?

Mr. Herrington: According to the best evidence available, conditions on the Penobscot River are better than they were in the past. In several other rivers in eastern Maine the conditions are much better than they were in the past, owing to the reduction in lumbering operations.

Mr. Underhill: Primarily in northern Maine?

Mr. Herrington: Yes. There are other streams in New England in which conditions would be satisfactory, but there are no adequate records available.

I would like to add that this is a program drawn up to suggest a way in which restoration work should be carried out with a view to the best chances of success; it is not a program now under way, because there are no funds available for it. It is a formulation of what should be done, looking to a sound program.

The President: Is a Federal program or a cooperative State program proposed.

Mr. Herrington: It doesn't matter where the funds come from, if they come from somewhere, because it is a worthy cause.

Dr. A. G. Huntsman: I should like to ask Mr. Herrington whether the group of rivers he has mentioned in eastern Maine can be said to have come back naturally, as a result of improved conditions, without any attempt at introduction of salmon into those waters?

Mr. Herrington: I have no record to show how good the fishing was in the past, so that it is impossible to make any definite statement. According to the local people the fishing is improved. They are quite enthusiastic about it now, and are apt to be carried away by their enthusiasm. Unfortunately we have no accurate record of any of the streams.

Dr. Huntsman: The point seemed to me that the Dennys River was blocked so that the salmon could not get up and spawn. Wasn't there a dam which prevented the fish from going up to spawn?

Mr. Herrington: I think possibly so. I do not believe it was entirely blocked. There has been some natural survival there, and of course there have been salmon planted throughout that region, both by the Federal Government and by the State. I am not sure to what extent planting in these rivers would cause the salmon to come back, or whether the improved fishing is accounted for by the small natural remnants which were there.

A SURVEY OF ACADEMIC QUALIFICATIONS FOR FISHERY BIOLOGISTS AND OF INSTITUTIONAL FACILITIES FOR TRAINING FISHERY BIOLOGISTS

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ABSTRACT

The perplexity of students, prospective students, and educators concerning requisite academic training for fishery biology has prompted a survey to provide basic and comparative data.

A questionnaire was circulated among the 68 fishery biologists employed by the Fish and Wildlife Service and an almost equal number of fishery biologists in the employ of various States, Provinces and private institutions which requested an evaluation of academic subjects in relation to undergraduate and early postgraduate training for eight phases of fishery biology. The results consist of a composite evaluation of fundamental courses as essential, desirable, optional, or not necessary expressed on a percentage basis.

Instruction in the form of specialized courses in fishery subjects and hydrobiology in the United States and Canada was determined by means of a second questionnaire submitted to a qualified faculty member of each of 80 of the principal universities and colleges. Forty-three schools now provide some instruction and facilities. The questionnaire also provided information on number of faculty, facilities and supervision for research, museum collections of aquatic animals, and biological stations.

INTRODUCTION

Among the thousands of inquiries from citizens received each year by the former Bureau of Fisheries and by the present Fish and Wildlife Service of the U. S. Department of the Interior are many requests for recommendations concerning the academic training necessary for biological positions in the Division of Fishery Biology. Other requests seek information relative to the universities and colleges in North America where specialized instruction and training in fishery subjects may be obtained.

In the past, any suggestions that were offered concerning academic training usually had to be made from a more or less personal viewpoint and obviously were unsatisfactory both from the standpoint of the Service and from that of the recipient. To provide a more reliable basis for answering the inquiries, a questionnaire was circulated among the 68 fishery biologists now employed by the Fish and Wildlife Service and 65 additional biologists in the employ of the various States, Canadian Provinces, and independent research institutions. The men receiving questionnaires were all experienced in investigations and hence well-qualified to evaluate the importance of academic training. The replies to the questionnaires (123 in all) provided such an interesting fund of information that it has been decided to make it available generally through publication in the *Transactions of the American Fisheries Society.*

For many years the former Bureau of Fisheries circulated in mimeographed form the results of a survey of instructional facilities that appeared in a report of the Committee on Aquiculture of the Division of Biology, National Research Council.[1] Since that information is now considerably out of date and because it embraced only some of the fresh-water phases of fishery biology it was believed that a new survey should be conducted that would encompass all of the various branches of present-day fishery biology, both marine and fresh-water. Recently, a questionnaire was submitted to members of the faculties of 80 of the leading universities and colleges in the United States and Canada which inquired concerning the course work, instructional and research facilities, museum collections, and biological stations supported by each. The replies to that questionnaire have supplied the data for a second part of this report, instructional and research facilities for training fishery biologists.

The cooperation of Mr. Charles E. Jackson, Assistant Director of the Fish and Wildlife Service, who submitted the questionnaire to academic institutions and the assistance of Mr. Elmer Higgins, Chief of the Division of Fishery Biology of the Service, who aided in the drafting of the questionnaires and submitted the questionnaire to fishery biologists are gratefully acknowledged.

The Field of Fishery Biology

The field of fishery biology has developed during recent years from a single line of endeavor into at least eight phases. In attempting to make a "break-down" classification of fishery biology, it is admitted that any system is more or less arbitrary and will be open to criticism from one viewpoint or another. The division of labor among the fishery biologists of the Fish and Wildlife Service appears to fall into at least eight classifications, which, however, are not mutually exclusive. In filling out questionnaires concerning recommendations for undergraduate and early postgraduate course work, many indicated that their answers were applicable to two or more phases. Thus, in the tabulations that follow there is some duplication so that the 123 questionnaires returned actually totalled 136 when they were distributed among the 8 phases of fishery biology as follows:

1. Marine fishery biology (41 replies)
2. Fresh-water fishery biology (55 replies)
3. Aquiculture (16 replies)
4. Fish pathology (13 replies)
5. Aquatic physiology (8 replies)
6. Oyster culture and physiology (9 replies)
7. Ichthyology (15 replies)
8. Oceanography (8 replies)

[1]Science, Vol. 71, 1930, pp. 265-266.

Although, as has been stated, these various phases may be assumed to indicate the specialties of fishery biologists, all investigators should have and do have training adequate to enable them to work in the immediately related phases. For example, marine fishery biology necessitates some knowledge of oceanography; fresh-water fishery biology implies also some knowledge of aquicultural methods, especially to the extent that "fish-management" work in interior lakes and streams enters into the duties of the investigator; aquiculture and fish pathology are a necessary combination for successful experimental fish-cultural work; both marine fishery biology and fresh-water fishery biology require some acquaintance with systematic ichthyology; and present-day systematic ichthyology has gone far beyond the sphere of pure taxonomy and relies upon natural history and ecology (as comprehended in fishery biology) for the analysis and interpretation of speciation and racial affinities. Aquatic physiology, which infers studies of water quality as related to the detection and measurement of the effects of natural, altered, or contaminated environments upon fishes and aquatic invertebrates, is allied closely to fishery biology and some aspects of aquiculture.

Undergraduate and Early Postgraduate Training

The recommendations for basic training in the various subjects common to the curricula of the larger colleges and universities are presented in Tables 1 to 4. In filling out the questionnaire the biologist was asked to evaluate the importance of the various subjects by designating them as *essential* (E), *desirable* (D), *optional* (O), or *not necessary* (NN). The recommendations have been computed on a percentage basis, for example in Table 1, for marine fishery biology, 2 per cent of the 41 questionnaires indicated that bacteriology was essential, 34 per cent held it to be desirable, 42 per cent optional, and 22 per cent not necessary. Without further explanation it is believed that the results of Tables 1 to 4 can be interpreted by the student, prospective student, or educator as indicating what subjects form or should form indispensable or desirable items in the collegiate training of a fishery biologist. If the value in the *essential* (E) column is 50 per cent or more it may be inferred that the prospective student must have training in that subject.

In addition to the subjects listed in the tables some of those who returned questionnaires recommended additional courses as essential or desirable, which should, for the most part, be pursued during advanced postgraduate study. These are listed below.

Marine fishery biology.—Physiological chemistry (biochemistry), histology, navigation, microtechnique, public speaking, logic (all desirable).

Fresh-water fishery biology.—Physiological chemistry (biochemistry), histology, surveying, microtechnique, business administration, public speaking, logic, advanced water analysis, algae (all desirable).

Table 1.—The relative importance of various academic subjects to training for marine and fresh-water fishery biology expressed as percentages of the total number of questionnaires related to each phase

[E, essential; D, desirable; O, optional; NN, not necessary]

Subject	Marine fishery biology (41)				Fresh-water fishery biology (55)			
	E	D	O	NN	E	D	O	NN
Bacteriology	2	34	42	22	16	52	25	7
Botany								
Elementary	54	37	9	....	84	11	5	....
Phanerogamic	5	17	55	23	13	34	42	11
Cryptogamic	12	37	37	14	22	42	31	5
Chemistry								
Elementary	100	....	....	....	95	5	....	....
Qualitative	39	49	10	2	35	53	7	5
Quantitative	37	44	17	2	31	48	16	5
Physical	24	20	32	24	13	20	42	25
Organic	30	34	34	2	24	51	20	5
Economics	20	34	26	20	11	24	41	24
English composition	90	10	....	....	85	15	....	....
French	17	63	15	5	25	51	16	8
Geology								
Elementary	10	34	34	22	35	36	25	4
Palaeontology	....	10	56	34	....	18	51	31
German	44	49	7	....	54	40	4	2
Geography	2	27	44	27	9	31	40	20
Mathematics								
Trigonometry	63	27	10	....	44	38	11	7
Analyt. geometry	39	49	10	2	29	31	22	18
Calculus	39	44	15	2	25	31	27	17
Statistics	90	10	....	....	84	16	....	....
Physics	61	32	5	2	69	24	5	2
Physiology	54	42	4	....	65	33	2	....
Zoology								
Elementary	100	....	....	....	100	....	....	....
Comp. anatomy	78	10	12	....	64	27	9	....
Embryology	71	27	2	....	64	27	5	4
Invertebrate	76	22	2	....	80	20	....	....
Entomology	15	34	36	15	62	29	9	....
Parasitology	7	68	20	5	25	50	25	....
Protozoology	9	54	32	5	18	53	29	....
Genetics	24	42	22	12	23	46	23	8
Systematic	66	27	5	2	55	36	9	....
Ecology	66	34	....	....	75	25	....	....
Limnology	24	54	20	2	89	7	4	....
Oceanography	39	51	10	....	10	48	20	22

Table 2.—The relative importance of various academic subjects to training for aquiculture and fish pathology expressed as percentages of the total number of questionnaires related to each phase

[E, essential; D, desirable; O, optional; NN, not necessary]

Subject	Aquiculture (16)				Fish pathology (13)			
	E	D	O	NN	E	D	O	NN
Bacteriology	25	56	19	....	70	15	15	....
Botany								
Elementary	88	6	6	....	100	....	....	....
Phanerogamic	12	44	25	19	23	23	15	39
Cryptogamic	25	31	25	19	31	23	15	31
Chemistry								
Elementary	100	....	....	....	92	8	....	....
Qualitative	63	31	6	....	68	16	16	....
Quantitative	50	25	25	....	61	23	16	....
Physical	13	6	56	25	23	....	46	31
Organic	44	31	25	....	54	23	23	....
Economics	....	44	31	25	7	31	31	31
English composition	81	19	....	....	76	8	8	8
French	31	31	25	13	61	23	8	8
Geology								
Elementary	50	31	19	....	....	38	31	31
Palaeontology	....	19	19	62	....	....	15	85
German	50	44	6	....	....	31	31	38
Geography	....	50	44	6	46	54	....	....
Mathematics								
Trigonometry	19	50	25	6	15	46	24	15
Analyt. geometry	13	25	25	37	8	23	31	38
Calculus	6	38	31	25	....	24	24	52
Statistics	81	19	....	....	69	15	8	8
Physics	75	19	6	....	62	22	8	8
Physiology	75	25	....	....	84	8	8	....
Zoology								
Elementary	100	....	....	....	100	....	....	....
Comp. anatomy	50	50	....	....	54	38	8	....
Embryology	50	44	....	6	54	31	15	....
Invertebrate	63	37	....	....	61	31	8	....
Entomology	63	25	12	....	54	23	23	....
Parasitology	44	56	....	....	77	23	....	....
Protozoology	12	70	12	6	69	31	....	....
Genetics	6	75	19	....	38	23	31	8
Systematic	31	38	25	6	46	23	23	8
Ecology	62	38	....	....	70	15	15	....
Limnology	94	....	6	....	77	15	8	....
Oceanography	6	38	38	18	....	8	46	46

Table 3.—The relative importance of various academic subjects to training for aquatic physiology and oyster culture and physiology expressed as percentages of the total number of questionnaires related to each phase

[E, essential; D, desirable; O, optional; NN, not necessary]

Subject	Aquatic physiology (8)				Oyster culture and physiology (9)			
	E	D	O	NN	E	D	O	NN
Bacteriology	100	....	....	....	33	44	23	....
Botany								
Elementary	100	....	....	....	89	....	....	11
Phanerogamic	12	88	....	....	11	67	11	11
Cryptogamic	25	75	....	....	56	33	....	11
Chemistry								
Elementary	100	....	....	....	100	....	....	....
Qualitative	62	38	....	....	66	34	....	....
Quantitative	75	25	....	....	66	34	....	....
Physical	62	38	....	....	44	44	12	....
Organic	62	38	....	....	56	44	....	....
Economics	12	25	63	....	11	11	33	45
English composition	88	12	....	....	89	11	....	....
French	50	25	25	....	22	67	11	....
Geology								
Elementary	38	50	12	....	67	22	11	....
Palaeontology	....	....	100	....	....	22	33	45
German	74	13	13	....	78	22	....	....
Geography	25	25	25	25	....	....	44	56
Mathematics								
Trigonometry	50	50	....	....	67	33	....	....
Analyt. geometry	62	25	13	....	33	45	22	....
Calculus	37	50	13	....	33	67	....	....
Statistics	75	....	25	....	56	33	11	....
Physics	100	....	....	....	89	11	....	....
Physiology	100	....	....	....	100	....	....	....
Zoology								
Elementary	100	....	....	....	100	....	....	....
Comp. anatomy	88	12	....	....	67	11	11	11
Embryology	88	12	....	....	78	11	11	....
Invertebrate	75	25	....	....	100	....	....	....
Entomology	50	37	13	....	22	22	11	45
Parasitology	25	75	....	....	22	22	11	45
Protozoology	25	50	25	....	22	67	11	....
Genetics	24	38	38	....	22	22	45	11
Systematic	38	38	12	12	44	44	12	....
Ecology	50	25	25	....	44	44	....	12
Limnology	75	25	....	....	44	44	12	....
Oceanography	....	75	25	....	56	33	11	....

Table 4.—The relative importance of various academic subjects to training for ichthyology and oceanography expressed as percentages of the total number of questionnaires related to each phase

[E, essential; D, desirable; O, optional; NN, not necessary]

Subject	Ichthyology (15)				Oceanography (8)			
	E	D	O	NN	E	D	O	NN
Bacteriology	20	33	33	14	13	62	25	....
Botany								
Elementary	73	27	....	....	76	12	12	....
Phanerogamic	....	53	47	....	....	38	50	12
Cryptogamic	14	53	33	....	25	38	37	....
Chemistry								
Elementary	93	7	....	....	100	....	....	....
Qualitative	20	66	7	7	62	38	....	....
Quantitative	13	60	20	7	62	38	....	....
Physical	7	33	33	27	50	25	25	....
Organic	13	47	33	7	25	50	13	12
Economics	....	33	33	33	....	25	38	37
English composition	80	20	....	....	75	25	....	....
French	20	60	20	....	38	50	12	....
Geology								
Elementary	33	40	20	7	25	25	50	....
Palaeontology	....	40	33	27	....	25	63	12
German	53	47	....	....	75	25	....	....
Geography	7	33	47	13	13	25	50	12
Mathematics								
Trigonometry	47	33	20	....	63	25	12	....
Analyt. geometry	33	41	13	13	50	38	12	....
Calculus	27	46	27	....	50	38	12	....
Statistics	60	40	....	....	63	25	12	....
Physics	40	33	20	7	63	37	....	....
Physiology	53	47	....	....	63	37	....	....
Zoology								
Elementary	100	....	....	....	100	....	....	....
Comp. anatomy	60	20	20	....	50	13	25	12
Embryology	60	33	7	....	50	25	13	12
Invertebrate	53	40	7	....	50	37	13	....
Entomology	27	40	33	....	13	37	13	37
Parasitology	27	40	33	....	....	63	25	12
Protozoology	13	40	47	....	....	75	25	....
Genetics	20	47	33	....	13	50	12	25
Systematic	80	20	....	....	50	25	13	12
Ecology	80	20	....	....	38	38	12	12
Limnology	66	27	7	....	63	25	12	....
Oceanography	27	46	27	....	100	....	....	....

Aquiculture.—Physiological chemistry (biochemistry), histology (desirable); water chemistry, nutrition (essential).

Fish pathology.—Physiological chemistry (biochemistry), medical pathology, histology, cytology, microtechnique (essential); pharmacology, serology (desirable).

Aquatic physiology.—Physiological chemistry (biochemistry), advanced physics, advanced physiology, plant physiology, advanced organic and inorganic chemistry, histology, cytology, microtechnique (essential); pharmacology, toxicology, nutrition, endocrinology, sanitary engineering (desirable).

Oyster culture and physiology.—Physiological chemistry (biochemistry), histology, cytology, microtechnique (essential); pathology, toxicology, nutrition, endocrinology (desirable).

Ichthyology.—Histology, microtechnique, logic, systematic botany (desirable).

Oceanography.—Advanced physics, navigation (essential); marine algae, meteorology, advanced calculus, advanced statistics (desirable).

The questionnaires were criticized by several persons who responded because they contained no specialized fishery or conservation courses. These were intentionally omitted because many universities and colleges offer none or have only irregular and scattered instruction and on the other hand the actual subject matter of such courses is so extremely variable that it would be difficult to include them in these lists. Specialized fishery courses for the most part are advanced studies requiring fundamental training in the physical and biological sciences. The second part of this paper will attempt to indicate to what extent specialized instruction is available at different North American institutions.

The Ideal Biological Training

The tendency to overspecialize during undergraduate days was noted by several who responded to the questionnaire. It was indicated that frequently students who become good research men in their respective fields nevertheless lack fundamental training in certain cultural subjects and in cognate fields. Some investigators called attention to the rather widespread deficiency among biologists and other scientists in the proper use of the English language and the lack of facility in writing good scientific papers. It will be noted in Tables 1 to 4 that the vast majority of the responses indicated English composition as essential and almost all of the small remainder considered it desirable. Several of the men who direct research activities of others stated that the biologists should have training in English composition and English literature beyond the minimum required for graduation by most universities and colleges. Institutions, in the opinion of a few, should be encouraged to provide substantial instruction in the proper use of bibliographic sources, in the analysis and

tabulation of data, and in the proper preparation of manuscripts for publication.

French and German were the only foreign languages listed in the questionnaire because, traditionally, candidates for the doctorate almost universally, and for the master's degree in some institutions, are required to pass examinations in those subjects. Undoubtedly German is very useful to the majority of fishery workers. On the other hand, various of the questionnaires indicated that another foreign language might be substituted for French with profit since Norwegian, Danish, Russian, Italian and even Japanese appear to be equally or more useful to the fishery biologist. Some institutions permit the substitution of one of these languages for French in meeting the language requirements for the doctorate.

No 4-year course will enable a student to acquire all of the essential and desirable special courses in addition to the necessary training in cultural fields. One or more years of postgraduate study should be undertaken if possible. It is hoped that the results of this questionnaire will provide a basis for judging the relative merits of various fields of instruction in the academic preparation for a career as a professional fishery biologist. Lest the student or prospective student be discouraged by the seemingly insurmountable array of course work, let him reflect upon the statements made by Dr. A. G. Huntsman, Director of the Fisheries Research Board of Canada, on the back of his questionnaire:

> "A fishery investigator, if he is to have a good chance of solving the problems with which he is confronted, requires a general training in the sciences and related fields with some cultural subjects as is very well appreciated. While special courses . . . . are definitely valuable I believe the most important matters are that he have such a thorough background in biology (zoology, botany and physiology) and physics that he can really tackle the common problem of an organism in a changing, largely physical, environment. If he is really able to investigate both the fish and its environment he is apt to go very far."

Courses in Fishery Biology

The number of academic institutions in the United States that offer specialized courses related to fishery biology has increased considerably during the last 15 years due to the growth of fishery science as a recognized profession and the ever-increasing number of opportunities for employment in the field. A questionnaire was sent to 80 of the leading institutions in the United States and Canada during May, 1940. Selection of the list of schools was made rather arbitrarily upon the basis of the size of the enrollment and membership in the American Association of Universities and Colleges. The replies indicated that only 43 institutions in the United States and Canada have any

facilities for training fishery biologists through special instruction and supervision, and that a smaller number have the necessary facilities for the development of specialists in the various branches of fishery biology. No claims are made for the completeness of the tabulations because some institutions that possibly should have appeared on the list may have failed to return the questionnaire. Time did not permit any follow-up procedure, but since the purposes of the survey were described in detail in a letter that accompanied each questionnaire it is felt that any institution that had special courses or facilities would have responded voluntarily. For the most part the data presented are exactly as submitted. Some personal judgment had to be exercised in coordinating the responses on a small number of the questionnaires so that they could be adapted to a condensed tabular presentation. Only those institutions that offer special courses and/or opportunities and facilities for research have been included in the tabulations and all negative replies were discarded without mention. Some few schools not mentioned herein indicated that while they offered no courses in the special fields at present they planned to do so as soon as the financial means of providing faculty members and facilities become available.

The number of regular and occasional courses in various subjects related to fishery biology is shown in Table 5 where the institutions have been arranged alphabetically by States. When it was difficult to determine the precise number of courses offered from the information supplied, the minimum number is indicated followed by a plus sign. The letter "V" is used to indicate that while no regularly scheduled courses are offered, personal guidance for individual study and/or instruction are available if there is sufficient demand. The classification of courses is that assigned by officials of the institutions and hence no claims can be made for the comparableness of subject matter in courses at different schools.

The number of faculty members teaching specialized fishery courses at the various schools is indicated in Table 6, differentiated as professors and instructors. Laboratory assistants have not been included. Sometimes the same faculty member teaches more than one or even the majority of the courses listed for a particular school. The availability of supervision and facilities for individual problem work and independent research is indicated by the letter "R." This evaluation of facilities is based upon statements of officials for personal knowledge is confined to but a small number of schools.

Biological Stations and Museum Collections

The fairly large number of summer biological stations and the two marine and one fresh-water station open throughout the year provide an opportunity for the fishery investigator to conduct research work on field problems and to pursue course work in some instances as well.

Table 5.—Number of courses in subjects related to fishery biology in the curricula of academic institutions

[Occasional courses indicated in parentheses, personal guidance or instruction on demand indicated by V, variable]

State or Province	Institution	Marine fishery biology	Fresh-water fishery biology	Syste-matic ichthy-ology	Physi-ology	Fish path-ology	Fish parasi-tology	General parasi-tology	Lim-nology	Ocean-ography	Fish culture
Ala.	Alabama Polytechnic Institute....	..	..	2	1	..	..	2	..	..	..
Calif.	Stanford University	3 (1)	2 (1)	2 (1)	4+	..	..	..	1 (1)	2 (1)	..
Calif.	University of California	1	..	..	2+	..	..	..	..	2	..
Colo.	University of Colorado	..	..	..	3+	..	..	1	1	..	..
Conn.	Yale University	1	..	..	1	..	..	1	1	1	..
Fla.	University of Florida	..	1	(1)	..	..	..	1	(1)	..	..
Ill.	University of Illinois	..	V	V	1+	V	..	2	V	..	..
Ind.	Indiana University	..	1	..	1	..	..	..	1	..	..
Iowa	Iowa State College.....	..	2	1	3	..	..	2	..	..	..
Iowa	State University of Iowa.....	..	V	..	..	..	..	..	V	..	..
Kan.	University of Kansas	..	..	V	..	..	..	1	1	..	..
Ky.	University of Kentucky	..	V	V	..	..	..	1	..	..	..
La.	Louisiana State University.....	2	2	..	6	..	2	2	..	..	..
Maine	University of Maine	V	..	1	1	..	..	1	..	..	1
Md.	University of Maryland	1	..	1	2	..	..	..	..	1	1
Mass.	Harvard University	V	..	V	4	V	..	1	1	1	..
Mass.	Massachusetts State College.....	..	..	..	..	..	..	..	..	..	1
Mich.	University of Michigan	V	2	3	3+	..	..	3	3	..	V
Minn.	University of Minnesota	..	1	2	2	..	..	3	1	..	..
Mo.	University of Missouri	..	V	..	6+	..	..	1	V	..	..
Mont.	University of Montana	..	1	1	1	..	..	1	V	..	..
Neb.	University of Nebraska	..	V	..	4	..	..	3	..	..	..
N. H.	University of New Hampshire ..	1	..	1	..	..	..	..	1	1	..
N. J.	Rutgers University	..	..	..	3	..	..	1	1	..	..
N. Y.	Cornell University	..	2	2	2	..	..	2	1	..	1
N. Y.	N. Y. State College of Forestry....	..	1	V	..	V	V	1	..	..	..
N. Y.	University of Rochester.....	..	..	V	..	..	..	..	..	..	..
N. C.	Duke University	1	V	V	2	..	..	2	..	1	..
N. C.	University of North Carolina.....	V	V	V	1	..	..	..	1 (1)	1	..
Ohio	Ohio State University.....	..	1	1	2	..	1	1	1	..	1
Ont.	University of Toronto.....	1	1+	1+	2+	..	V	1+	1+	1	..
Ore.	Oregon State College.....	..	..	1	3	..	(1)	1	..	..	..
R. I.	Rhode Island State College.....	V	..	V	V	..	..	..	..	V	V
Sask.	University of Saskatchewan	..	1	1	1	..	..	1	1	..	..
Tenn.	University of Tennessee	..	..	..	5	..	..	3	1	..	1
Texas	A. & M. College of Texas.....	..	V	1	..	..	..	..	..	..	..
Utah	University of Utah.....	..	..	V	..	..	..	1	V	..	..
Utah	Utah State Agri. College.....	..	V	..	..	..	..	1	1	..	..
Va.	University of Virginia	..	V	..	..	..	..	1	V	..	..
Wash.	University of Washington	2+	3+	2	4+	1	1	1	1	3+	3
W. Va.	University of West Virginia.....	..	V	..	..	..	..	1	V	..	..
Wis.	University of Wisconsin	..	V	..	1	..	..	2	2	..	..
Wyo.	University of Wyoming	..	1	..	3	..	..	3	..	..	..

Table 6.—Number of faculty teaching fishery biology and related courses at various academic institutions

Wis.	University of Wisconsin	..	V	..	1	..	..	2	2	..	..	..
Wyo.	University of Wyoming	..	1	..	3	..	..	3	..	..	..	..

Table 6.—Number of faculty teaching fishery biology and related courses at various academic institutions

[Numbers outside of parentheses, professors; numbers within parentheses, instructors; R, supervision and facilities for independent research]

State or Province	Institution	Marine fishery biology	Fresh-water fishery biology	Systematic ichthyology	Physiology	Fish pathology	Fish parasitology	General parasitology	Limnology	Oceanography	Fish culture
Ala.	Alabama Polytechnic Institute	..	.. R	1	1	..	..	1	..	..	.. R
Calif.	Stanford University	4 R	2 R	2 R	7 R	..	..	..	4 R	2 R	..
Calif.	University of California	1	..	..	..	..	..	..	..	3 (3) R	..
Colo.	University of Colorado	..	.. R	..	2 (1) R	..	.. R	1 R	1 R	..	..
Conn.	Yale University	1 (1) R	..	..	1 R	..	..	1 R	1 R	1 R	..
Fla.	University of Florida	..	1 R	(1)	..	..	..	1	1 R	1 R	..
Ill.	University of Illinois	..	..	..	2 R	1 R	..	2 R	2 R	..	..
Ind.	Indiana University	..	1 R	..	1 R	..	..	..	1 R	..	..
Iowa	Iowa State College	..	(1) R	(1) R	2 R	..	.. R	1 R	..	..	..
Iowa	State University of Iowa	..	1	..	..	..	..	..	1	..	..
Kan.	University of Kansas	..	..	1	..	..	..	1 R	1 R	..	..
Ky.	University of Kentucky	..	..	..	..	..	..	(1)	..	..	..
La.	Louisiana State University	3 R	3 R	..	4 R	..	2	2 R	..	..	..
Maine	University of Maine	..	..	(1) R	1	..	..	1 R	..	..	(1)
Md.	University of Maryland	1 R	..	1 (1) R	1 R	..	..	..	..	1 R	1 R
Mass.	Harvard University	.. R	..	.. R	5 (1) R	.. R	..	1 R	1 R	1 R	..
Mass.	Massachusetts State College	..	..	..	..	..	..	..	..	..	1
Mich.	University of Michigan	.. R	1 (1) R	2 (1) R	3 + R	..	.. R	4 R	2 R	..	..
Minn.	University of Minnesota	..	1 R	2 R	1 (1) R	..	..	1 (1) R	1 R	..	..
Mo.	University of Missouri	..	1	..	6 + R	..	..	1 R	1 R	..	..
Mont.	University of Montana	..	1 R	1 R	1	..	..	(1)	1 (1) R	..	..
Neb.	University of Nebraska	..	1 R	..	4 R	..	..	1 (1) R	..	..	..
N. H.	University of New Hampshire	2 (1) R	.. R	2 R	..	..	..	..	1 R	1 R	..
N. J.	Rutgers University	..	..	..	2	..	..	1 R	1 R	..	..
N. Y.	Cornell University	..	1 (1) R	1 (1) R	3 R	..	..	2 R	1 (1) R	..	1 R
N. Y.	N. Y. State College of Forestry	..	1 R	1	..	1	1	1	..	..	..
N. Y.	University of Rochester	..	..	1 R	..	..	..	..	..	..	..
N. C.	Duke University	1 R	.. R	.. R	1 (2) R	..	.. R	1 R	..	1 R	..
N. C.	University of North Carolina	1	1	1	1	..	..	..	1 R	1 R	..
Ohio	Ohio State University	..	1 R	1 R	2 R	..	1 R	1 R	1 R	..	1 R
Ont.	University of Toronto	1 R	2 (3) R	1 R	..	.. R	.. R	1 R	2 (3) R	1 R	..
Ore.	Oregon State College	..	..	1 (1) R	2 (1) R	..	1 R	2 R	..	..	..
R. I.	Rhode Island State College	2 (1) R	..	1 R	1 R	..	..	..	..	2 (1) R	..
Sask.	University of Saskatchewan	..	1 R	1	2	..	..	1 R	1 R	..	1
Tenn.	University of Tennessee	..	..	..	1 (3) R	..	..	1 (2) R	1 (1) R	..	..
Texas	A. & M. College of Texas	..	1	1 R	..	..	..	..	..	..	1 R
Utah	University of Utah	..	..	1 R	..	..	..	1 R	1 R	..	..
Utah	Utah State Agri. College	..	1	..	..	..	..	1 R	1 R	..	..
Va.	University of Virginia	..	1	..	..	..	..	1 R	1 R	..	..
Wash.	University of Washington	2 (1) R	2 (1) R	(1) R	4 + R	1 R	1 R	1 R	1 R	3 + R	2 R
W. Va.	University of West Virginia	..	1	..	..	..	..	1 R	1	..	..
Wis.	University of Wisconsin	..	1 R	..	1 R	..	.. R	1 R	1 R	..	..
Wyo.	University of Wyoming	..	1	..	1	..	..	1 R	..	..	..

Table 7.—List of biological stations for teaching purposes and/or research affiliated with academic institutions in the United States and Canada, list of collections of fishes, and highest degrees conferred by institutions

State or Province	Supporting institution	Biological Station	Purpose[1]	Open	Museum collections[2]	Highest degree conferred[3]
Ala.	Alabama Polytechnic Institute	None	.....	.....	I—local	M
Calif.	Stanford University	Hopkins Marine Station	C R	All year	I—extensive	D
Calif.	University of California	Scripps Institution of Oceanography	C R	All year	I—moderate	D
Colo.	University of Colorado	25 miles NW of Boulder	C	Summer	I—local	D
Conn.	Yale University	None	.....	.....	I—moderate	D
Fla.	University of Florida	Welaka	R	Summer	I—local	D
Ill.	University of Illinois	None—summer field courses	.....	.....	I—moderate	D
Ind.	Indiana University	Winona Lake	C R	Summer	None	D
Iowa	Iowa State College	None	.....	.....	I—local	D
Iowa	State University of Iowa	Iowa Lakeside Laboratory	C R	Summer	None	D
Kan.	University of Kansas	None	.....	.....	I—local	D
Ky.	University of Kentucky	None	.....	.....	I—local	M
La.	Louisiana State University	Grand Isle	C R	Summer	I—local	D
Maine	University of Maine	Lamoine	R	Summer	None	M
Md.	University of Maryland	Chesapeake Biological Laboratory	R	Summer	S—local	D
Mass.	Massachusetts State College	None	.....	.....	I—local	M
Mass.	Harvard University	None	.....	.....	I—extensive	D
Mass.	———	Marine Biological Laboratory	C R	Summer	S—local	—
Mass.	———	Woods Hole Oceanographic Institution	R	Summer	S—local	—
Mich.	University of Michigan	Douglas Lake	C R	Summer	I—extensive	D
Minn.	University of Minnesota	Itasca State Park	C R	Summer	I—local	D
Mo.	University of Missouri	None	.....	.....	I—local	D
Mont.	University of Montana	Flathead Lake[4]	C R	Summer	I—local	M
Neb.	University of Nebraska	None	.....	.....	I—local	D
N. H.	University of New Hampshire	Isle of Shoals	C R	Summer	I—local	M
N. J.	Rutgers University	New Brunswick	R	Summer	None	D
N. Y.	Cornell University	None	.....	.....	I—moderate	D
N. Y.	N. Y. State College of Forestry	Huntington Wildlife Station	C	Summer	I—local	D
N. Y.	University of Rochester	None	.....	.....	I—local	D
N. C.	Duke University	Beaufort	C R	Summer	None	D
N. C.	University of North Carolina	Highlands	R	Summer	I—local	D
Ohio	Ohio State University	Franz Theodore Stone Laboratory	C[5] .....R	All year	I—local	D
Ont.	University of Toronto	Algonquin Park	R	Summer	I—moderate	D
Ore.	Oregon State College	Coos Bay	C R	Summer	I—local	D
R. I.	Rhode Island State College	Narragansett Marine Laboratory	R	Summer	S—local	M
Sask.	University of Saskatchewan	Prince Albert National Park	R	Summer	I—local	M
Tenn.	University of Tennessee	None	.....	.....	None	M
Texas	A. & M. College of Texas	None	.....	.....	I—local	D
Utah	University of Utah	None	.....	.....	I—local	M
Utah	Utah State Agri. College	None	.....	.....	None	M
Va.	University of Virginia	Mt. Lake	C R	Summer	None	D
Wash.	University of Washington	Friday Harbor	C R	Summer	I—moderate	D
W. Va.	University of West Virginia	None	.....	.....	I—local	M
Wis.	University of Wisconsin	Trout Lake	R	Summer	I—local	D
Wyo.	University of Wyoming	Medicine Bow National Forest	C R	Summer	I—local	M

[1]R—research; C—course work.
[2]I—institution; S—biological station.
[3]M—M.A. or M.S.; D—Ph.D.
[4]Temporarily discontinued.
[5]Courses in summer only.

These biological stations are listed in Table 7 opposite the names of the institutions with which they are affiliated, or if independent no institution name appears.

Study collections of preserved fishes, amphibians and invertebrates are essential for research and training of biological investigators. The location of such museum collections in connection with institutions and laboratories is also indicated in Table 7. An attempt has been made to denote roughly the scope of the collections by the use of a simple adjective, but the evaluations depend principally on the descriptive data supplied by officials. This list does not include museums not affiliated with academic institutions or biological stations. Thus several large museum collections such as those of the U. S. National Museum, the American Museum of Natural History, and the Field Museum, or others, have not been mentioned, although they have large study collections of fishes and other aquatic organisms available for the use of qualified and properly accredited investigators.

Postgraduate Study and Degrees

The courses listed in Tables 5 and 6 are open only to advanced or postgraduate students in the majority of instances. All require a varying number of prerequisite elementary and intermediate courses in the same or in cognate fields. The calibre of the research facilities and supervision at any institution frequently determines what advanced degrees the institution awards. The highest degree conferred at the various schools mentioned in the lists where courses and research in special phases of fishery biology may be pursued is indicated by symbol in the right-hand column of Table 7.

Conclusion

The survey of academic qualifications has attempted to present objectively the recommendations for undergraduate and postgraduate training of fishery biologists in the light of the experience and judgment of men in the field. Its only purpose is to provide the student, prospective student, and educator with some form of guidance in planning an adequate biological education for entrance into the field of professional fishery biology.

A survey of specialized course work, research facilities, number of faculty, biological stations and museum collections was designed to serve as a guide to students who seek information concerning the specialized fishery biology courses that are available at different institutions and by such a composite presentation may be assisted in their attempts to determine which school provides instruction and facilities in conformity with their interests and objectives.

Finally, it is urged emphatically that the comparative data should not constitute a sole basis for decision concerning any institution.

[1]Courses in summer only.

[2]I—institution; S—biological station.
[3]M—M.A. or M.S.; D—Ph.D.

Other, more intrinsic factors, should be considered with regard to each school a student contemplates attending. He should by all means correspond with faculty members and obtain detailed descriptions of courses and facilities before he makes a decision. He should visit the institution if possible before making a definite decision to enroll. It must be remembered that there are a great number of very good schools in the United States and Canada qualified to provide an excellent foundation for fishery biology that have not as yet included any pure fishery or hydrobiological courses in their curricula.

This survey has not included the subjects of short courses in field methods, or fish culture which may be offered to persons who are not interested in a complete college education or in a career as a biological specialist. Likewise, the growing fields of marketing and technology that represent another form of specialized education for work related to the fisheries are not considered. All these, practical fish culture, field methods, marketing and technology, might be similarly surveyed by persons intimately associated with them.

INCREASED GROWTH RATE OF ROCK BASS, *AMBLOPLITES RUPESTRIS* (RAFINESQUE), FOLLOWING REDUCTION IN THE DENSITY OF THE POPULATION[1]

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ABSTRACT

Lakes with dense population of stunted fish have long presented a difficult problem to fishery biologists. In 1937 the Michigan Institute for Fisheries Research began a series of planned experiments in the reduction of the populations of over-crowded lakes. In one of these experiments the fish of the south basin of Standard Lake were poisoned with rotenone (derris root). Samples of the rock bass population were taken at the time of the poisoning, in September, 1937. During 1939 and 1940 further collections were made in order to determine the effect of the population reduction. An increased growth rate, too great to be accounted for by any normal growth fluctuation, had occurred in fish of all ages. The reduction of the density of the populations is therefore suggested as one solution to the problem of lakes with large populations of stunted fish.

INTRODUCTION

The problem of lakes in which populations of stunted fish occur has troubled fishery biologists for some time (Hubbs and Eschmeyer, 1938). Numerous small lakes in northern Michigan were found by Eschmeyer (1937, 1938) to contain populations of stunted perch. The majority of lakes on which he worked were otherwise suited for trout. He therefore completely removed the perch (by poisoning), and the lakes were restocked successfully with trout.

Many of the lakes that contain an over-abundance of undersized fish and few "keepers" are not suited, however, for trout or other cold-water species. Standard Lake, located at the junction of the boundaries of Cheboygan, Charlevoix, and Otsego Counties, Michigan, was such a lake. Standard Lake has an area of 32.5 acres, and a maximum depth of 31 feet, and is divided nearly equally into a north basin of 16.5 acres and a south basin of 16.0 acres. The two parts of the lake are connected by a channel which is shallow but of sufficient depth (about 1 foot) and width (about 200 feet) to permit the free passage of fish.

In order to test the effect of reducing the total population of fish, 110 pounds of derris root (rotenone content 5 per cent) were put into the south basin on September 6, 1937. The channel was blocked off with sand bags to prevent the movement of fish to or from the south basin during the treatment with derris root, and to restrict the action of the poison to that part of the lake. Dr. R. W. Eschmeyer, formerly of the Institute for Fisheries Research, was in charge of this

[1]Contribution from the Michigan Institute for Fisheries Research.

experiment. Following his resignation, the writer took over the investigation.

All the fish killed by the poison that could be found were picked up, to be weighed and counted by species (Table 1). A total of 20,192 fish (1,262 per acre) was collected. These fish weighed 348.7 pounds (21.8 pounds per acre). The species of fish found in the basin were: Yellow perch (*Perca flavescens*), rock bass (*Ambloplites rupestris*), red-bellied dace (*Chrosomus erythrogaster*), fine-scaled dace (*Pfrille neogaea*), Iowa darter (*Poecilichthys exilis*), mud minnow (*Umbra limi*), golden shiner (*Notemigonus crysoleucas auratus*), black-nosed shiner (*Notropis h. heterolepis*), blunt-nosed minnow (*Hyborhynchus notatus*), and the common sucker (*Catostomus c. commersonnii*).

Table 1.—Number and weight of fish in the south basin of Standard Lake on September 6, 1937

Species	Number	Average weight (ounces)	Total weight (pounds)
Perch	4,827	0.47	146.4
Rock bass	1,233	0.70	53.9
Forage fish	14,054	0.07	62.9
Suckers	78	17.50	85.5
Total	20,192	.....	348.7

On the basis of the random sample which was taken to the laboratory, the lake contained only 2.7 legal-sized game fish per acre (2.4 yellow perch, and 0.3 rock bass). The entire 16-acre basin contained 42 legal-sized game fish, or less than two limit catches. That a scarcity of legal-sized fish was characteristic of the lake was verified by interviews with local inhabitants.

After a sufficient time had been allowed for the powdered derris root to lose its potency, the sand bags were removed. The unharmed fish of the north basin were thus allowed to move freely throughout the entire lake.

Further collections of rock bass were made in Standard Lake in May, June, and October, 1939, and July, 1940, to obtain comparative material for the determination of any changes in growth rate that might have followed the reduction in the numbers of this species. Most of the 1939 and 1940 samples of 228 rock bass were taken in experimental gill nets (5 by 125 feet, with five sections of different mesh sizes, varying from 1½ to 4 inches, stretched measure); a few fish were caught by hook and line. At the time of the poisoning a random sample of 182 rock bass was saved.

Method of Calculating Lengths

Scale samples were taken from all the fish collected, and "key" scales (scales from an exactly specified location on the body) were taken from most of them. The age of each fish was determined by counting the number of annuli on the scale.[2] At a magnification of

[2]The validity of the annulus on rock bass scales as a true year mark was proved by Hile (1941).

X 44.3 measurements were made of the scale image from the focus outward along the middle of the most nearly anterior inter-radial space.

The body-scale relationship was determined from measurements of the "key" scales to be described by a straight line with an intercept on the abscissa at 15 millimeters. The following formula therefore was used for the calculation of growth:

$$L_n = 15 + S_n \frac{L_T - 15}{S_T},$$

where L_n = the length of the fish in millimeters at the end of the n^{th} year of life,
S_n = the scale radius within the n^{th} annulus,
L_T = the standard length of the fish in millimeters at the time of capture,
S_T = the total scale measurement.

Change in Growth Rate Following Reduction in Density of Population

By means of the formula given in the preceding section, the growth history of each specimen was calculated from its scale measurement. The grand average calculated lengths of males and females for each year of life are shown in Table 2. The table does not include the calculated lengths for the small collection of 1940. The average standard lengths of the age groups at capture are given in Table 3. Since the only difference in the growth of the sexes lies in the more rapid growth of the males in the later years of life, the following remarks apply to both sexes.

The rock bass of the 1939 and 1940 collections were notably larger at the time of capture than were fish of the corresponding age and sex in the 1937 sample (Table 3). The difference seems to be attributable to an accelerated growth following the reduction in the numbers of

Table 2.—Average calculated length of rock bass from Standard Lake at the end of each year of life. Grand averages based on the successive addition of the weighted average growth increments

[Number of specimens in parentheses]

Sex and year of capture	Calculated lengths in millimeters at end of each year of life					
	1	2	3	4	5	6
MALES						
1937	32 (57)	52 (47)	70 (35)	79 (22)	....	....
1939	32 (75)	54 (75)	76 (55)	98 (39)	124 (19)	146 (2)
FEMALES						
1937	32 (56)	52 (48)	69 (38)	72 (21)	83 (2)	....
1939	30 (84)	52 (84)	71 (73)	92 (54)	116 (23)	....

Table 3.—Length of rock bass in Standard Lake at time of capture

[Number of specimens in parentheses]

Age group	Average standard length in millimeters at time of capture					
	Males			Females		
	[1]1937	[2]1939	[2]1940	1937	1939	1940
[3]I	57	88	....	57	84	....
	(10)	(16)	....	(8)	(22)	....
II	73	89	91	70	85	85
	(12)	(20)	(11)	(10)	(11)	(6)
III	84	105	....	80	89	....
	(13)	(16)	....	(17)	(19)	....
IV	88	108	140	83	102	....
	(22)	(20)	(1)	(19)	(31)	....
V	....	114	....	90	115	126
	....	(17)	....	(2)	(23)	(1)
VI	....	118	....	....	....	135
	....	(2)	....	....	....	(1)

[1]All fish of the 1937 collection were taken on September 6.
[2]In 1939 the specimens were taken in May, June, and October—about two-thirds in May and June; in 1940 the specimens were taken in July.
[3]The 1939 data for age-group I are considered unreliable due to possible gear selectivity.

this fish. The data are doubly impressive when it is considered that about two-thirds of the 1939 specimens were taken in May and June, when at this latitude, according to recent investigations (Beckman, Ms), the growth of the fish has just begun, whereas the entire 1937 sample was collected on September 6, when the seasonal growth was almost completed. The difference in size appears to be relatively the greatest for age-group I, but the data for this group are not believed to be reliable for the present comparison, since the gill nets employed for the collection of 1939 specimens may have taken only the larger individuals of the age group. This belief was supported by the comparison of the lengths of the I-group fish with the length distribution of rock bass from 1½-inch mesh gill nets given by Hile (1941).

That the increased growth followed the reduction in the density of the population is demonstrated more clearly by an analysis of the growth increments for each year of life by calendar years (Tables 4 and 5). A comparison of growth in the same year of life, regardless of age-group, shows a close agreement in their calculated increments up to the time of poisoning in 1937, whereas the increments for 1938 and 1939 were considerably larger. The possible explanation that the increased increment was due to chance is negated by the consistency of the findings, for the calculated increments for the 5 years prior to the poisoning agreed very closely. Another possible explanation might be offered, namely, that the original sample taken at the time of poisoning was not representative, having come from only one basin, where there may have been a distinct population with slower growth than in the basin which was not poisoned. This explanation also is negated by the fact that the growths calculated from the 1939 and 1940 collections agreed very well with those made from the 1937 collections, and the increased growth was made only after the poisoning. That the greater growth in the calendar years 1938 and 1939 was due to normal fluc-

tuation in growth rates such as those found by Hile (1941) for the rock bass and Hubbs and Hubbs (1933) for bluegills (*Lepomis macrochirus*), pumpkinseed sunfish (*Lepomis gibbosus*) and the hybrids (*Lepomis macrochirus* × *Lepomis gibbosus*) is rendered very improb-

Table 4.—Growth increments by calendar years for male rock bass from Standard Lake, during each year of life, before and after reduction in numbers by poison

[For number of specimens see Table 3]

Computed for year of life	Computed from age group	Calculated growth in millimeters for calendar year						
		Before poisoning					After poisoning	
		1933	1934	1935	1936	1937	1938	1939
1	II	....	....	30	....	32	36	....
	III	....	32	....	34	....	....	....
	IV	33	....	30	[1](32)	....	....	....
	V	....	32	....	....	....	....	....
	VI	31	....	....	....	....	....	....
2	II	....	....	....	22	....	35	38
	III	....	....	18	....	20	....	....
	IV	....	20	....	18	(15)	....	....
	V	....	....	18	....	....	....	....
	VI	....	21	....	....	....	....	....
3	III	....	....	....	16	....	40	....
	IV	....	....	18	....	14	(53)	....
	V	....	....	....	14	....	....	....
	VI	....	....	18	....	....	....	....
4	IV	....	....	....	9	....	30	(29)
	V	....	....	....	....	12	....	....
	VI	....	....	....	10	....	....	....
5	V	....	....	....	....	....	28	....
	VI	....	....	....	....	9	....	....
6	VI	....	....	....	....	....	....	22

[1]Although conforming with the other data, the figures in parentheses are based on too few specimens to be of reliable significance, and are not considered in the discussion in the text.

Table 5.—Growth increments by calendar years for male rock bass from Standard Lake, during each year of life, before and after reduction in numbers by poison

[For number of specimens see Table 3]

Computed for year of life	Computed from age group	Calculated growth in millimeters for calendar year							
		Before poisoning						After poisoning	
		1932	1933	1934	1935	1936	1937	1938	1939
1	I	....	....	....	....	34	....	35	....
	II	....	....	....	32	....	30	....	....
	III	....	....	32	....	32	....	....	....
	IV	....	32	....	30	....	....	....	....
	V	[1](31)	....	30	(23)	....	....	....	....
	VI	....	....	(32)	....	....	....	....	....
2	II	....	....	....	....	20	....	39	35
	III	....	....	....	18	....	19	....	....
	IV	....	....	21	....	18	....	....	....
	V	....	(25)	....	17	(23)	....	....	....
	VI	....	....	....	(19)	....	....	....	....
3	III	....	....	....	....	16	....	29	....
	IV	....	....	....	18	....	16	....	....
	V	....	....	(16)	....	17	(14)	....	....
	VI	....	....	....	....	(13)	....	....	....
4	IV	....	....	....	....	8	....	27	....
	V	....	....	....	(6)	....	12	(41)	....
	VI	....	....	....	....	....	(13)	....	....
5	V	....	....	....	....	(6)	....	24	(19)
	VI	....	....	....	....	....	....	(30)	....
6	VI	....	....	....	....	....	....	....	(24)

[1]Although conforming with the other data, the figures in parentheses are based on too few specimens to be of reliable significance, and are not considered in the discussion in the text.

able by the consistency of occurrence of the small increments over a period of 5 years prior to the poisoning. It appears valid to conclude, therefore, that the reduction in the density of the population was the factor responsible for the improved growth.

The increase in growth rate that has been found to follow a reduction in the numbers of stunted fish not only is in agreement with expectation on biological grounds, but also suggests a method that may prove to be sound and effective procedure in fish management. Too often in the past the problem of stunted fish has been aggravated by the legal protection of the runts and even by further stocking.

Summary

1. Standard Lake, Michigan, has long had a reputation as a poor fishing lake. Undersized fish were over-abundant but fish of legal size were extremely scarce.

2. An experiment to test the effect of reducing the density of the population was begun in 1937 when the fish in one basin of the lake were poisoned.

3. From scale samples taken in 1939 and 1940, computations were made of the growth rates before and after the poisoning. The growth of rock bass of all ages improved following the poisoning.

4. The reduction of the density of population therefore may be a solution to the problem of improving fishing in lakes overrun with stunted fish.

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AN INVESTIGATION OF THE USE OF OXYGEN IN TRANSPORTING TROUT

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ABSTRACT

Oxygenated tanks, for transporting fish, depend on the production of small bubbles of the gas, which rise through the water in the tank. A part of the oxygen dissolves before the bubbles reach the surface, so that the oxygen content of the water is increased. An investigation has been made of the relation of the quantity of oxygen liberated, the size of the tank, the depth of the water and water temperature to (1) the quantity of oxygen which dissolves in the water and (2) the weight of trout that may be carried. Desirable factors in tank design and operation are discussed.

INTRODUCTION

The use of tanks for the transportation of live trout has increased rapidly during the past decade. Unlike earlier distribution methods, which depended on the agitation of water for aeration, tanks require the continuous addition of large amounts of dissolved oxygen. This may be accomplished in several ways, of which the two most widely used are circulation of water and liberation of oxygen gas. Only the latter will be discussed.

The equipment selected for the tests is used by the New York State Conservation Department, and will differ in detail from that used by other agencies. The general principles of operation should apply, however, to any tank using a system of oxygen liberation. Two sizes of tanks are used in New York. The smaller is 48 inches long, 18 inches wide and 28½ inches deep. The larger tanks are 8 feet long, 4 feet wide and are divided by crosswise partitions into compartments, each of which is similar to one of the small tanks. Throughout the remainder of this paper the word "tank" will be used to designate the smaller type.

Oxygen from commercial cylinders is diffused in the bottom of the tank through "Aloxite" liberators.[1] Each liberator is a sphere 1⅜ inches in diameter. A nipple is fastened in the sphere, to the outer end of which a rubber hose may be attached to carry oxygen from the supply, into the center of the liberator. The oxygen passes through the porous material of the liberator to its surface and is released in the water in small bubbles. A part of each bubble dissolves before it reaches the surface. Each tank is supplied with two liberators, which lie on the bottom, one near each end. The supply lines are equipped with valves so that the flow of oxygen to each liberator may

[1]Aloxite Brand Aerator Stones, No. 220. Manufactured by The Carborundum Co., Niagara Falls, N. Y.

be regulated. Hatchery practice in the use of the tanks varies, but on the average a liberator is regulated to deliver about 1 cubic foot per hour, when the depth of water in the tank is 15 inches.

Determinations of dissolved oxygen content were made by the Rideal-Stewart modification of the Winkler method, described by the American Public Health Association (1936). Carbon-dioxide content of the water was not determined. The flow of oxygen was measured by collecting all the gas from each liberator in a flask filled with water, immersed and inverted in the tank.

Experimental Observations

The first experiments were designed to determine the effectiveness of the liberators in increasing the amount of dissolved oxygen in the water. No fish were placed in the tank during the tests. The water was obtained from the regular hatchery supply, whose gaseous content averaged: oxygen, 10 p.p.m.; carbon-dioxide, 4.5 p.p.m.; and the pH was 7.0 to 7.2.

1. *Relation of oxygen content of tank water to the effectiveness of the liberators.*—Fresh spring water at a temperature of 50° F. was placed in the tank to a depth of 15 inches. Two liberators, which had previously been set to deliver 1 cubic foot per hour per liberator, were placed in the tank. Duplicate oxygen determinations were made at 15-minute intervals. The relationship of dissolved oxygen to time (Figure 1) shows that the amount of oxygen rose rapidly at first, but the longer the experiment continued the slower was the rate of increase. Thus, as the amount of oxygen increased the rate of increase became lower. Eventually a saturation point would be reached. For a given rate of flow from the liberators the higher the amount of oxygen in solution the lower is the rate of increase.

2. *Relation of rate of flow from liberators to their effectiveness.*—The same procedure described was repeated for delivery rates of ¼, ½ and 2 cubic feet per hour per liberator. Each experiment was made in duplicate, the first with water from the hatchery supply and the second with water whose dissolved oxygen content had been lowered to about 1.5 p.p.m. The low value of dissolved oxygen was produced by placing fish in the tank and leaving them until they were badly distressed. They were removed and the experiment initiated. Since in each case the data from the two tests coincided over the range covered by both experiments, only one curve is given for each pair of tests (Figure 1).

As might be expected, the amount of dissolved oxygen increases more rapidly at the higher delivery rates. However, an examination of the curves shows, for example, that the rate of increase with a flow of 2 cubic feet per hour per liberator is not double the rate of increase for a flow of 1 cubic foot per hour. In other words, the higher the delivery rate, the lower the effectiveness or efficiency of the liberator

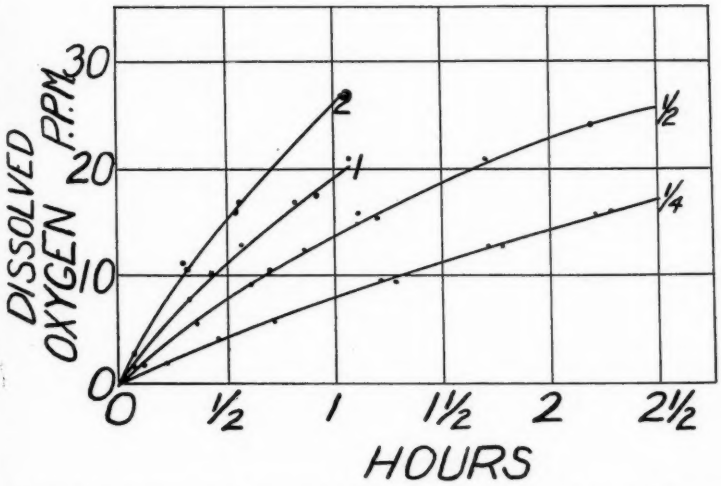

Figure 1.—The quantity of dissolved oxygen in a tank containing water 15 inches deep in relation to time. Individual curves represent flow from liberators at rates of ¼, ½, 1, and 2 cubic feet per hour.

becomes in producing an increase in dissolved oxygen. In order to examine carefully this relationship, algebraic equations were obtained for each of the curves. Exponential equations fitted the data in each case, the equations being of the form

$$Q = A\ (1 - e^{-ct})$$

in which Q = dissolved oxygen in p.p.m.
t = time in hours with zero time when $Q = 0$
e = the base of natural logarithms
c and A = constants to be determined for each equation.

The constants for each of the four curves were determined by trial and error. In order to facilitate the determination, the curves have been extended to zero in each case. By differentiating the equation for Q, an equation for dQ/dt is obtained. DQ/dt is the algebraic way of writing "rate of change of Q with respect to time" or in other words, the rate of increase of dissolved oxygen in p.p.m. By manipulation of the equations for Q and dQ/dt the following equation may be obtained:

$$dQ/dt = c\ (A - Q)$$

This equation means that the rate of increase of dissolved oxygen is inversely related to the p.p.m. of oxygen at any particular time. This relation is plotted for values of dissolved oxygen from 0 to 20 p.p.m. which is the approximate range covered by the experiments and is the range of importance in the operation of tanks (Figure 2).

Since dissolved oxygen is expressed in parts per million of the water in which it is dissolved, each part per million for a given amount of water represents a definite weight of oxygen. Thus, the rate of increase of dissolved oxygen expressed in parts per million per hour may be converted into rate of increase in pounds per hour. The rate of delivery of oxygen from each liberator, which is expressed in cubic feet per hour may also be converted to pounds per hour. Then percentage efficiency of the liberators is equal to the rate of increase of dissolved oxygen (in pounds per hour) divided by the rate of delivery from the liberators (in pounds per hour). Values have been calculated for flows of ¼, ½, 1 and 2 cubic feet per hour per liberator (Figure 3). In each instance the efficiency decreases as the amount of oxygen in solution increases. For delivery rates of ¼ and ½ cubic foot per hour the efficiency is essentially the same, but for rates of flow of 1 and 2 cubic feet per hour per liberator it is considerably lower.

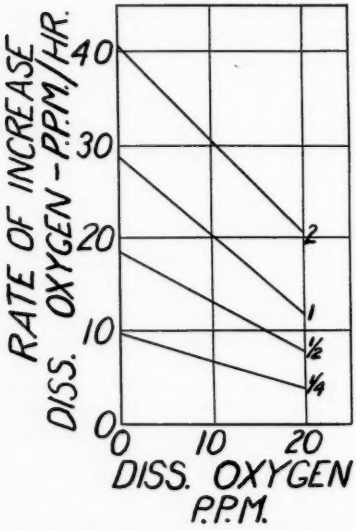

Figure 2.—Relation of quantity of dissolved oxygen to rate of increase for conditions of Figure 1.

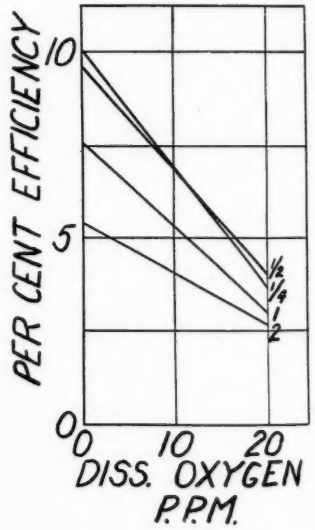

Figure 3.—Relation of dissolved oxygen to liberator efficiency for conditions denoted in Figure 1.

In practical application it seems desirable to keep delivery rates at or below ½ cubic foot per hour per liberator and if necessary to increase the number of liberators.

The higher the oxygen content of the water, the lower is the efficiency of a liberator. The higher the rate of flow the lower is the efficiency of a liberator. For the type of liberator used in the tests a flow of slightly more than 1 cubic foot per hour produces an effect known to tank operators as boiling of the water. Many have believed that an increase in flow, beyond this point, would not increase the amount of dissolved oxygen produced, but the tests show that such is not the case.

3. *Relation of the number of liberators to the effect of each liberator in producing dissolved oxygen.* Only one experiment was made on this point, in which one liberator was operated with a flow of 2 cubic feet per hour and the result compared with the previous experiment in which two liberators were used, each with a flow of 2 cubic feet per hour, making a total of 4 cubic feet per hour. Beginning at an initial value of 10.4 p.p.m., it required 65 minutes to produce an increase of 10 p.p.m. with one liberator and 30 minutes with two liberators. Obviously the efficiency (ratio of pounds increase of dissolved oxygen to pounds of oxygen liberated) of one liberator acting alone is less than that of two acting together.

Under identical conditions one liberator acting alone is slightly less efficient than two acting together. Inasmuch as the difference in efficiency between one and two liberators is small it might be neglected in practical tank operation.

4. *Relation of depth of water to efficiency of liberators.*—The procedure described in Experiments 1 and 2 was repeated using depths of water of 6, 10, 15, 20, and 25 inches. A rate of flow of 1 cubic foot per hour and a water temperature of 50° F. was used for studying each depth. The rates of increase of dissolved oxygen and the liberator efficiency were calculated as described in Experiment 2 for the single value of dissolved oxygen of 10 p.p.m. (Table 1).

Thus, the deeper the water the higher is the efficiency of the liberator. For the best utilization of oxygen emphasis in tank design should be placed on depth rather than length or width.

5. *Relation of water temperature to efficiency of liberators.*—The procedure described in Experiments 1 and 2 was repeated using water

Table 1.—Efficiency of liberator at an oxygen content of 10 p.p.m. with two liberators in tank, oxygen flow of 1 cubic foot per hour per liberator, temperature 50° F.

[See text for definition of efficiency]

Depth of water (inches)	Percentage efficiency
6	3.2
10	3.8
15	5.0
20	6.2
25	7.4

temperatures of 35, 40, 52 and 60° F. A rate of flow of 1 cubic foot per hour per liberator and a depth of water of 15 inches was used (Table 2).

Over a range of dissolved oxygen content of 10 to 25 p.p.m., water temperature has little effect on the efficiency of a liberator, in spite of the well-known fact that the saturation point falls as the temperature rises. For the practical purpose of tank operation the effect of temperature on the liberator efficiency may be disregarded.

Table 2.—Increase of dissolved oxygen at various water temperatures with two liberators in the tank, oxygen flow of 1 cubic foot per hour per liberator and a depth of 15 inches of water

Water temperature (Degrees Fahrenheit)	Dissolved oxygen (p.p.m.)		
	Initial	After ½ hour	After 1 hour
35	10.0	19.0	25.9
40	10.0	18.9	25.0
45	10.0	18.8	25.8
50	10.0	18.0	24.5
60	10.0	18.2	24.0

6. *Variability of liberators.*—No experiments were performed to determine the variability in operation of individual liberators. However, experiments made in 1938 agree with like experiments made in 1939 using other liberators. Also one change of liberators was made, by accident, during the 1939 experiments. Two experiments, repeated after the change, gave identical results to those made before. Judging from limited data, one may expect small variations among liberators of the kind used in these tests.

7. *Relationship of water temperature to oxygen consumption of 5½-inch brown trout.*—This and the following experiments were designed to measure the effect of various factors on the transportation of trout. The data from Experiments 1 to 6 were used in interpreting the results. The fish in all tests were 5½-inch brown trout (*Salmo fario*).

For each test the fish were starved 12 hours. They were weighed in a tub and poured into the tank. Sufficient water was already in the tank so that after the fish were put in the total depth was 15 inches. Spring water at 52° F., the same temperature as that in which the fish had been kept, was used. Two oxygen liberators, which had previously been set to deliver 1 cubic foot per hour per liberator, were placed in the tank at the same time as the fish. Icing of the tank was begun at once and the water rapidly brought to the desired temperature and held at that point. An exception is the experiment at 60° F. for which the water was allowed to warm to 60° F. before the beginning of the experiment. In all tests the tank remained stationary. Duplicate oxygen determinations were made every 15 minutes for the first ½ hour and then at 30-minute intervals. Tests were made at 35, 45, 52 and 60° F.

The fish were excited when first placed in the tank but gradually became quiet. Actual counts disclosed a respiration rate of 90 per

minute at the beginning of each test while at the end it had dropped to 70 per minute. The normal value was between 60 and 65 per minute.

The excitement of the trout was reflected in the amounts of dissolved oxygen which dropped rapidly for the first ½ hour and then rose, in each instance (Figure 4). This fact indicates that the oxygen consumption is highest during the period following loading. Therefore, the early period during a shipment is the critical time and the availability of sufficient oxygen during this period is a major determinant of the carrying capacity of the tank. Oxygen determinations made on the New York State railway fish car during 36-hour shipments confirm this finding. High delivery rates of oxygen should be used during the first hour, after which the flow may be reduced. Recognition of this principle has permitted substantial increases in tank loads.

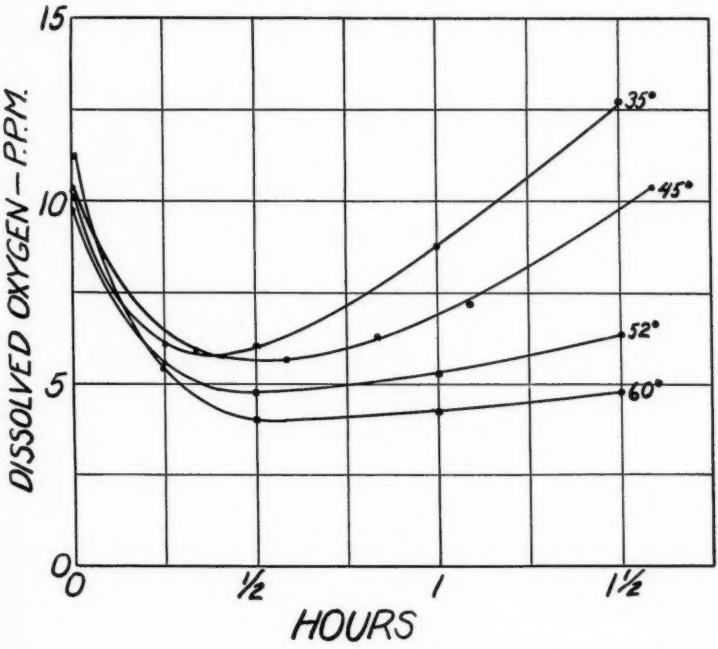

Figure 4.—The relationship between dissolved oxygen and time in a tank with water 15 inches deep supplied with oxygen at a flow of 1 cubic foot per hour from each of two liberators. Temperatures of the water in degrees F. are indicated on the curves. Tanks contained 55 pounds of 5½-inch brown trout.

Using the amount of the recovery of the dissolved oxygen as an indicator, it is seen that the oxygen consumption was greater at high than at low temperature.

8. *Relationship of rate of delivery of oxygen to the oxygen depletion by 5½-inch brown trout.*—The procedure described in Experiment 7 was repeated. In each test a temperature of 52° F. was maintained and 55 pounds of 5½-inch brown trout were carried. Rates of oxygen flow of ⅕, ⅓, ½, 1 and 2 cubic feet per hour per liberator were used. The smaller the rate of flow the lower is the minimum value of the dissolved oxygen (Figure 5). After the minimum value is reached an increase in oxygen takes place for all flows except ⅕ cubic foot per hour. The increases are most rapid for the higher rates of flow, since the amounts of dissolved oxygen produced far exceed the demand of the fish. In the test at ½ cubic foot per hour per liberator, one fish died at the end of 20 minutes, which was 20 minutes before the oxygen reached its low point of 3.4 p.p.m. In the test at ⅓ cubic foot per hour per liberator two fish died after 30 minutes and two later during the experiment. The lowest oxygen value for this test was 3 p.p.m. In the test at ⅕ cubic foot per hour per liberator no fish died during the first 45 minutes. After that interval fish were "rolling over" continuously and were greatly distressed. As they became distressed they were removed and placed in fresh water. The lowest value of dissolved oxygen for this test was 2.5 p.p.m. A curve has been included in Figure 5 which shows the results of a test in which the fish were not placed in the tank until 8 minutes after the oxygen had been turned on. A flow of oxygen of 1 cubic foot per hour per liberator was used, and other conditions were identical with those in the other tests. Since the amount of dissolved oxygen had been increased before the introduction of the fish the minimum value was higher than in the corresponding test.

Oxygen depletion is dependent upon the rate of liberation and the initial amount present. Depletion of oxygen may be reduced by turning on oxygen for 10 or 15 minutes before fish are loaded. This point is particularly important at hatcheries whose water supply has a low dissolved oxygen content.

9. *Relationship of length of starvation to oxygen consumption of 5½-inch brown trout.*—The procedure described in Experiments 7 and 8 was repeated. In each test 55 pounds of fish were placed in the tank in which the water temperature was 52° F. and oxygen was introduced at the rate of 1 cubic foot per hour per liberator. Tests were made with fish starved 2, 12, 24 and 48 hours. No significant differences were noted in the oxygen consumption during any of these tests. It is concluded that, for 5½-inch brown trout, the starvation period does not affect oxygen consumption or the ability of the fish to withstand short trips. It was observed that in those tests where the fish were starved for 2 and 12 hours there was an accumulation of pollution in the water. It is possible that such pollution may have a

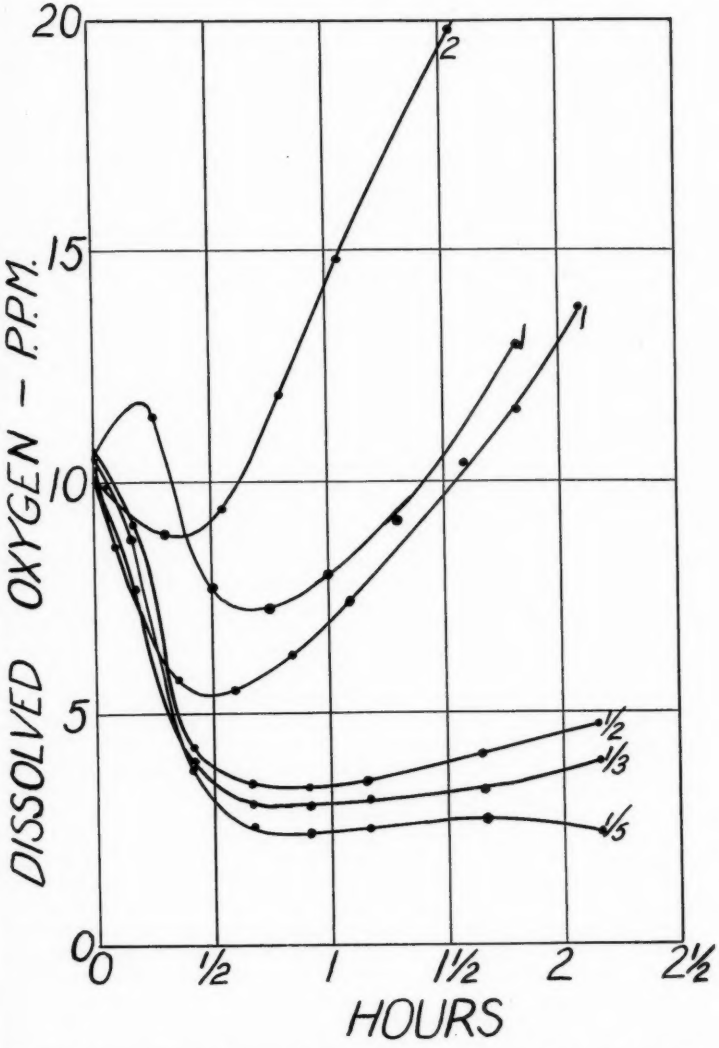

Figure 5.—Relationship of dissolved oxygen content to time during the transportation of 55 pounds of 5½-inch brown trout in a tank with water 15 inches deep at a temperature of 45° F. Figures at the upper most end of each curve denote the oxygen flow from each of two liberators used, expressed in cubic feet per hour.

toxic effect on the fish during long shipments. The factor of starvation is not important in transporting fish for short distances.

10. *Effect of motion of tank on oxygen consumption of 5½-inch brown trout.*—The procedure used in Experiment 7 was repeated with 55 pounds of fish per tank, a water temperature of 52° F. and an oxygen flow of 1 cubic foot per hour per liberator. The fish were starved 24 hours. The tank was mounted on a truck and driven over a rough road continuously throughout the experiment, except for stops to take water samples and temperature readings. This test was repeated a second time and the results not only were practically identical but were the same as those obtained during the previous experiment under the same conditions except that the tank remained stationary. It is tentatively concluded that motion had little effect on oxygen consumption, at least during the critical period following loading. Tests made on the New York State railway fish-car, previously referred to, indicate that motion has little, if any, effect on oxygen consumption during long shipments. The effect of a combination of lack of starvation and motion was not investigated.

11. *Relationship of density (weight of fish per cubic foot of water) to the oxygen consumption of 5½-inch brown trout.*—Using the method of Experiment 7 a series of tests was made in which loads ranging from 30 to 85 pounds of fish were carried with an oxygen flow of 1 cubic foot per hour per liberator and a temperature of 45° F. No curves are presented for these tests since the only significant finding was that oxygen consumption increased with the density or increased weight of fish carried.

In another series of tests 55 pounds of fish were held in a tank supplied with oxygen at a rate of 1 cubic foot per hour per liberator, and at a water temperature of 52° F. In the first test the procedure was the same as previously. The second test was made with the tank divided in half by a cross-wise water-tight partition and all fish and both oxygen liberators were placed in the one-half of the tank. In the third test one-quarter of the tank was used in the same way. Although the minimum value of dissolved oxygen in the three tests was nearly the same (5.5 p.p.m. in the whole tank, 4.5 p.p.m. in the half tank and 4.75 p.p.m. in the quarter tank) the fish carried well in the first two but in the quarter tank test were "rolling over" at the end of 12 minutes and were distressed until the end of the experiment. In each test the dissolved oxygen content increased after the minimum value was reached. The fish in the quarter tank test appeared never to have recovered from their early excitement due to their crowded condition and perhaps to the continual body contact. Under optimum conditions a tentative limit to the safe density of 5½-inch brown trout in transit may be set at 14⅔ pounds per cubic foot of total volume, a density which corresponds to the half tank experiment or a load of 110 pounds per whole tank.

Another test was made with the quarter tank in which the liberators

were placed in the tank and the oxygen allowed to reach 16 p.p.m. before the fish were introduced. The dissolved oxygen content dropped very rapidly and the fish were in distress at the end of a few minutes. In still another test the water in which the fish were weighed was allowed to build up a high dissolved oxygen value so that when the fish were placed in the tank the dissolved oxygen was 21.4 p.p.m. A very high rate of flow (unmeasured) was used but at the end of 15 minutes the fish showed signs of distress (the oxygen had dropped to 13 p.p.m.) and the flow was further increased. The fish became quieter and were carried for 1 hour without loss. The oxygen was then turned off (dissolved oxygen content, 27.7 p.p.m.) and at the end of 7 minutes dissolved oxygen content had decreased to 9.7 p.p.m. and the fish were very badly distressed.

Increased excitement of fish when congested in very heavy loads was reported by Prévost and Piché (1939). They alleviated this condition by the use of horizontal screens which provided a uniform vertical distribution of fish.

It is noteworthy that with very heavy concentrations of trout more than 10 p.p.m. of dissolved oxygen were required, while the normal minimum value is usually considered to be about 3 p.p.m. The result of this test suggests that the maximum rate at which fish can remove oxygen from water is directly dependent on the dissolved oxygen content. Following this theory one would expect that a continuously excited fish would require a high dissolved oxygen content in order to be able to remove its minimum oxygen requirement from the water. Although this theory explains the results, the experiment furnishes no proof of its validity.

It is concluded that a density of 14⅔ pounds per cubic foot (total volume of water and fish), is a tentative upper limit of tank capacity for 5½-inch brown trout. With a density of 29⅓ pounds per cubic foot the minimum allowable value of dissolved oxygen is between 10 and 15 p.p.m. With a load at a concentration of 29⅓ pounds per cubic foot the condition of the trout is precarious at all times.

Summary

The efficiency of an oxygen liberator in producing dissolved oxygen is, (1) practically independent of water temperature, between 35° and 60° F.; (2) directly related to the depth of water; (3) inversely related to the oxygen flow per liberator; and (4) inversely related to the concentration of dissolved oxygen.

The oxygen consumption of 5½-inch brown trout during shipment rises rapidly as the water temperature is increased over a range of 35° to 60° F.

Motion of the tank probably has a negligible effect on oxygen consumption.

Starving fish before shipment has little or no effect on oxygen con-

sumption. The only noticeable result when unstarved fish were carried was an accumulation of undigested food in the water. It is believed that on long trips this accumulation might become toxic to the fish.

Trout are excited when first placed in the tank, and high rates of respiration and oxygen consumption are induced. The excitement is gradually reduced so that if sufficient oxygen is supplied the dissolved oxygen reaches a minimum and starts to rise during the first 45 minutes.

In designing tanks to be supplied with oxygen, it is important to note that the liberator efficiency is approximately twice as great with a depth of 20 inches of water as it is with 6 inches of water. For best oxygen utilization in a tank depth of water is important. Since liberator efficiency is greatest when the oxygen flow from each liberator is small, it is economical to provide a large number of liberators per tank.

Practical suggestions for the safe operation of tanks supplied with oxygen by liberators are as follows:

1. A large amount of oxygen should be supplied during the first hour of a shipment. The oxygen should be turned on for a few minutes before the fish are loaded. After the first hour the oxygen flow may be reduced.
2. When possible weighing and counting of fish should be done on the day before shipment in order to reduce the excitement due to handling.
3. Icing of the tank should begin as soon as the fish are loaded. The temperature should be maintained at a low value during the entire shipment.
4. If fish manifest distress during transportation, believed to be caused by lack of oxygen, the flow from each liberator should be increased greatly since it will take some time to build up a safe oxygen content even at a rapid delivery rate.

The experimental results and conclusions of this paper apply only to 5½-inch brown trout and they should not be applied specifically to other species or sizes of fish without additional experimentation.

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PARASITES OF FISH OF ALGONQUIN PARK LAKES

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ABSTRACT

In the study of the parasites of fish from lakes in Algonquin Park, Ontario, 560 fish of 22 species were examined and 84.3 per cent carried at least one form. Many of the fish carried larval trematodes which have fish-eating birds as their definitive hosts. Lakes containing smallmouth black bass had several species of fish infested with larval cysts of the cestode, *Proteocephalus ambloplitis* (Leidy). Fish from lakes that did not contain smallmouth black bass did not carry this cestode. *Proteocephalus fluviatilis* Bangham, described previously only as a parasite of black basses in streams, was secured in black bass from seven Algonquin Park lakes. A leech, *Actinobdella triannulata* Moore, not previously reported as a parasite of fish was found on 24 per cent of the common suckers. Ten species of fish examined were of the family Cyprinidae. Of these minnows, 64.4 per cent were infested with at least one species of parasite. The parasites of the minnows were of few different species and the majority of the parasites were larval. The 12 remaining species of fish had 97.5 per cent infestation in those that were examined. The distribution of fish parasites from the 11 lakes where parasitized fish were secured is discussed.

During the latter part of July and during August, 1939, a preliminary survey was conducted on the parasitization of fish from the following lakes in Algonquin Park, Ontario: Dixon, Proulx, Opeongo, Brewer, Galeairy, Smoke, Costello and Amikeus. In addition, smallmouth black bass were obtained by creel-census workers from Cache, Whitefish and Rock Lakes. Several members of the staff of the Ontario Fisheries Research Laboratory assisted in the collection and identification of fish examined, and their assistance is gratefully acknowledged.

Of 560 fish belonging to 22 species, 472 or 84.3 per cent carried at least one species of parasite. All species of fish that were available were used in this study, except the lake trout. Parasites of the lake trout, *Cristivomer n. namaycush* (Walbaum) were being studied by another worker at the laboratory. A parasitization of 84 per cent is a rather high degree of infestation when young fish and minnows are included in the survey. Bangham and Hunter (1939) reported a 60 per cent infestation from a study of parasites of Lake Erie fish. During this survey of Lake Erie 2,156 fish representing 79 species were examined. In 1938 the writer examined 1,380 Florida fish belonging to 45 species and found 1,218 or 88.2 per cent parasitized with at least one form.

In general the parasitization of the Algonquin Park fish was very similar to that of the fish from Oneida Lake (Mueller and Van Cleave, 1932; Van Cleave and Mueller, 1932 and 1934). Many parasites which were not taken from Lake Erie fish but had been obtained at

Oneida Lake were taken from the same host at the Algonquin Park lakes.

Fish from too few areas were examined to obtain an adequate idea of the distribution of fish parasites and no concept of seasonal distribution can be given as a result of a study over so short a period. As will be seen from the discussion of parasites of individual species of fish, the degree of parasitization and the types of parasites varied in the fish from different lakes.

In the discussion of parasitization by species of fish which follows, the parasites for each species are listed in order of abundance, the number in parentheses following the species of parasite indicates the number of individuals carrying the designated parasite. The asterisk preceding the name of the parasite indicates an immature stage.

CISCO, *Leucichthys artedi* LeSueur
(Examined 16; infested 15)
Ergasilus caeruleus Wilson (15)
**Proteocephalus laruei* Faust (4)

Ciscoes were secured from Proulx Lake where they were taken from the deeper water by gill nets. The gill copepods, *Ergasilus caeruleus*, were found in large numbers.

LAKE WHITEFISH, *Coregonus clupeaformis* (Mitchill)
(Examined 10, all infested)
Proteocephalus laruei Faust (9)
Ergasilus sp. (7)
Leptorhynchoides thecatus (Linton) (3)
Crepidostomum cooperi Hopkins (2)
Spinitectus gracilis Ward and Magath (1)

All of these whitefish from Lake Opeongo had light infestations. The nematode, *Cistidicola stigmatura* Leidy, which is often found in the air bladder of whitefish, was not found.

MENOMINEE WHITEFISH, *Prosopium quadrilaterale* (Richardson)
(Examined 10, all infested)
Ergasilus sp. (7)
Crepidostomum faronis (Müller) (6)
Proteocephalus laruei Faust (4)
Crepidostomum cooperi Hopkins (2)

These fish were taken in the same gill nets with the common whitefish. The parasites of the two forms are very similar. The Menominee whitefish was the only host found for the trematode, *C. faronis*.

SPECKLED TROUT, *Salvelinus fontinalis* (Mitchill)
(Examined 12; infested 5)
Myxosporidia (5)
Trichodina sp. (1)

No speckled trout were obtained from the lakes in Algonquin Park; those examined were supplied by a small hatchery near the park head-

quarters. The unidentified myxosporidian was found in small cysts in the kidneys of the hosts.

NORTHERN SUCKER, *Catostomus catostomus* (Forster)
(Examined 4; infested 3)
Octospinifer macilentus Van Cleave (2)
Hepaticola bakeri Mueller and Van Cleave (1)
Ergasilus caeruleus Wilson (1)
Glaridacris catostomi Cooper (1)
**Triganodistomum* sp. (1)

All of the northern suckers were taken in gill nets from Lake Opeongo.

COMMON SUCKER, *Catostomus commersonnii* (Lacépède)
(Examined 53; all infested)
Triganodistomum attenuatum Mueller and Van Cleave (26)
Glaridacris catostomi Cooper (23)
Octospinifer macilentus Van Cleave (21)
Pomphorhynchus bulbocolli Linkins (16)
Octomacrum lanceatum Van Cleave and Mueller (13)
Actinobdella triannulata Moore (13)
Triganodistomum simeri Mueller and Van Cleave (6)
Glaridacris confusus Hunter (5)
Ergasilus caeruleus Wilson (5)
Hepaticola bakeri Mueller and Van Cleave (4)
**Eustrongylides* sp. (2)
Neoechinorhynchus sp. (2)
**Proteocephalus* sp. (1)
Gyrodactylidae (1)
**Tetracotyle* sp. (1)
**Clinostomum marginatum* (Rudolphi) (1)
Rhabdochona sp. (1)

The first four forms named in the above list were secured from three common suckers taken from Dixon Lake. All of the parasites in the list above except gill flukes were obtained from 24 suckers from Lake Opeongo. The acanthocephalan, *P. bulbocolli*, was found in only two of the Lake Opeongo suckers while this parasite was secured from 10 of 13 suckers from Proulx Lake and in 1 out of 8 from Smoke Lake. The brown leech, *A. trilineatus*, was taken from the gill cavities of 1 suckers from Lake Opeongo and in 1 of 3 from Costello Lake. These leeches usually were found attached to the inside of the operculum with an infected area showing through. Often from 2 to 5 leeches were found in the gill cavity of a single sucker. This form was encountered on no other host. *T. attenuatum* was taken from common suckers in all of the five lakes but was most abundant in Lake Opeongo since 19 of the 24 fish yielded this form. *T. simeri* was less abundant and not so widely distributed. *O. lanceatum* was secured from the

gills of common suckers from the five lakes. This form was first described by Van Cleave and Mueller (1934) who gave *Octobothrium sagittatum* Wright as a synonym. The latter species was reported from *Catostomus teres*. Van Cleave and Mueller wrote concerning this species: "Although Wright notes that the habitat of his material was uncertain, it is presumed that it was of Canadian origin, and probably from some locality in the Toronto region." The same species was taken from the gills of a black-nosed minnow from Proulx Lake.

NORTHERN CREEK CHUB, *Semotilus a. atromaculatus* (Mitchill)
(Examined 36; all infested)
Rhabdochona cascadilla Wigdor (11)
**Neascus ambloplitis* Hughes (11)
**Neascus vancleavei* (Agersborg) (11)
Allocreadium lobatum Wallin (4)
**Clinostomum marginatum* (Rudolphi) (3)
Neoechinorhynchus sp. (1)
**Neascus* sp. (1)
**Triganodistimum* sp. (1)
Gyrodactylidae (1)
**Agamonema* sp. (1)

Creek chubs from different locations showed considerable variations in the forms carried. All of 11 chubs from Amikeus Lake had *N. ambloplitis* as integumentary cysts. No chubs from other locations had this form. Only one *R. cascadilla* was taken from the Amikeus Lake fish whereas all of 10 from Dixon Lake and 9 of 19 from Proulx Lake yielded this parasite. *N. vancleavei* was secured from all of the Dixon Lake chubs and in one from Amikeus Lake. *A. lobatum* and *C. marginatum* were taken from the Proulx Lake chubs. One chub from Mud Creek carried a single *Neoechinorhynchus* sp., many larval *Triganodistimum* sp., and specimens of *R. cascadilla*.

NORTHERN DACE, *Margariscus margarita nachtriebi* (Cox)
(Examined 12; infested 3)
**Neascus ambloplitis* Hughes (3)
Rhabdochona cascadilla Wigdor (1)

All minnows of this species were taken from Proulx Lake.

FINE-SCALED DACE, *Pfrille neogaea* (Cope)
(Examined 29; infested 19)
**Neascus ambloplitis* Hughes (18)
**Agamonema* sp. (4)
Gyrodactylidae (1)

The fish belonging to this species were taken at Costello Creek and Amikeus Lake. The one carrying gill flukes was taken at Costello Creek, while those having larval nematodes came from Amikeus Lake.

NORTHERN RED-BELLIED DACE, *Chrosomus eos* Cope
(Examined 26; infested 8)
**Neascus ambloplitis* Hughes (4)
**Agamonema* sp. (3)
**Fluke (2)
Pomporhynchus bulbocolli Linkins (1)

All of four fish of this species from Proulx Lake were without parasites. Those with larval flukes and *P. bulbocolli* came from Costello Creek. The fish with larval nematodes were taken from Amikeus Lake. Fish from both of these latter localities bore *N. ambloplitis.*

GOLDEN SHINER, *Notemigonus crysoleucas* (Mitchill)
(Examined 3; all infested)
**Neascus ambloplitis* Hughes
The three fish were secured from Amikeus Lake.

NORTHERN BLACK-NOSED SHINER, *Notropis h. heterolepis* (Eig. and Eig.)
(Examined 12; infested 8)
**Neascus ambloplitis* Hughes (6)
**Ligula intestinalis* (Linnaeus) (2)
Octomacrum lanceatum Van Cleave and Mueller (1)
Gyrodactylidae (1)
Acanthocephala (1)
**Neascus* sp. (1)

One of four black-nosed shiners from Proulx Lake carried *O. lanceatum,* one unidentified acanthocephalan form and three gill flukes. Six of seven from Smoke Lake had *N. ambloplitis* cysts. One *L. intestinalis* was secured from the body cavity of a fish. Another black-nosed shiner from Dixon Lake had a single *L. intestinalis.*

NORTHERN COMMON SHINER, *Notropis cornutus* (Mitchill)
(Examined 38; infested 31)
Rhabdochona cascadilla Wigdor (15)
Allocreadium lobatum Wallin (10)
Gyrodactylidae (10)
**Neascus ambloplitis* Hughes (9)
**Neascus vancleavei* (Agersborg) (6)
**Tetracotyle* sp. (2)
Acanthocephala (2)
**Clinostomum marginatum* (1)
**Neascus* sp. (1)

These common shiners came from Brewer, Smoke, Proulx, Dixon and Opeongo Lakes and from Costello Creek. The same species of parasites were secured from the hosts in most of these regions. Ten of 11 common shiners from Proulx Lake had gill flukes and 2 of 10 from Smoke Lake carried a similar species. All of the fish infested

with *N. vancleavei* were from Smoke Lake. The largest number of different species from fish of a single location were obtained from the common shiners of Smoke Lake.

BRASSY MINNOW, *Hybognathus hankinsoni* Hubbs
(Examined 8; infested 3)
**Neascus ambloplitis* Hughes (3)
Octobothrium sp. (1)

All of the minnows of this species came from Amikeus Lake. The gill fluke, *Octobothrium* sp., appears to be new.

BLUNT-NOSED MINNOW, *Hyborhynchus notatus* (Rafinesque)
(Examined 26; infested 12)
**Neascus ambloplitis* Hughes (11)
**Ligula intestinalis* (Linnaeus) (1)
**Agamonema* sp. (1)
**Tetracotyle* sp. (1)

One of seven fish from Smoke Lake yielded cysts of *Tetracotyle* sp. The remaining parasitized minnows came from Amikeus Lake.

FAT-HEADED MINNOW, *Pimephales promelas* Rafinesque
(Examined 4; infested 1)
**Neascus ambloplitis* Hughes (1)
The fat-headed minnows were obtained from Amikeus Lake.

BROWN BULLHEAD, *Ameiurus nebulosus* LeSueur
(Examined 65; all infested)
Gyrodactylidae (44)
Corallobothrium fimbriatum Essex (39)
Alloglossidium geminus Mueller (36)
Allocreadium ictaluri Pearse (24)
**Proteocephalus ambloplitis* (Leidy) (16)
Phyllodistomum staffordi Pearse (8)
Crepidostomum ictaluri (Surber) (6)
**Clinostomum marginatum* (Rudolphi) (6)
Rhabdochona sp. (6)
Alloglossidium corti (Lamont) (5)
Spinitectus gracilis Ward and Magath (2)
Dichelyne cotylophora (Ward and Magath) (2)
Vietosoma parvum Van Cleave and Mueller (1)
Leptorhynchoides thecatus (Linton) (1)
Myxosporidia (1)
Capillaria sp. (1)
**Neascus vancleavei* (Agersborg) (1)
**Agamonema* sp. (1)
**Bothriocephalus* sp. (1)
Crepidostomum cornutum (Osborn) (1)
Pomphorhynchus bulbocolli Linkins (1)

The brown bullheads were taken from the following lakes: 22 from Opeongo, 13 from Proulx, 23 from Dixon and 7 from Smoke. The four most abundant species of parasites were secured from one-third to one-half of the bullheads from each lake. Cysts of *P. ambloplitis* were found only in bullheads from Smoke and Opeongo Lakes. These lakes have the definitive host of this species, the smallmouth black bass. *C. marginatum* and *Rhabdochona* sp. were taken from the Dixon Lake fish. None of the parasites of the brown bullhead appeared to cause great damage to the host.

AMERICAN EEL, *Anguilla bostoniensis* (LeSueur)
(Examined 1; infested)
Proteocephalus macrocephalus (Creplin) (1)
Azygia longa (Leidy) (1)
Bothriocephalus claviceps (Goeze) (1)
Leptorhynchoides thecatus (Linton) (1)

A single eel measuring 38 inches was taken from a trap net in Opeongo Lake.

YELLOW PERCH, *Perca flavescens* (Mitchill)
(Examined 58; all infested)
**Neascus ambloplitis* Hughes (46)
**Proteocephalus ambloplitis* (Leidy) (25)
Gyrodactylidae (17)
Bunodera sacculata Van Cleave and Mueller (17)
Crepidostomum cooperi Hopkins (17)
Proteocephalus pearsei La Rue (13)
**Clinostomum marginatum* (Rudolphi) (12)
Dichelyne cotylophora (Ward and Magath) (5)
**Bothriocephalus* sp. (5)
Glochidia (Mollusca) (5)
Proteocephalus ambloplitis (Leidy) (3)
Illinobdella sp. (2)
**Neascus vancleavei* (Agersborg) (2)
Azygia angusticauda (Stafford) (2)
**Leptorhynchoides thecatus* (Linton) (1)
Spinitectus sp. (1)
Rhabdochona sp. (1)
**Agamonema* sp. (1)
Bucephalus elegans Woodhead (1)
*Microphallidae (1)

Seventeen different species of parasites were encountered in the 37 yellow perch from Lake Opeongo. The perch from this lake often were dotted with metacercariae of *P. ambloplities* in pigmented integumentary and flesh cysts. Larval plerocercoids of *P. ambloplitis* were encysted in 22 of the Lake Opeongo yellow perch. This host formed a different type of cyst about *P. ambloplitis* larva than that formed by

other fish infested by this parasite. The cyst wall was a hard, round structure in the perch, while in other forms it was a soft, semi-transparent membrane. The type of cyst in the yellow perch appears to retard the growth of the larva. These cysts often were encountered within the stomach and intestinal walls. As with other species of fish, no perch infested with *P. ambloplitis* were taken from Proulx or Dixon Lakes. Three out of four adult yellow perch from Galeairy Lake near Whitney were each carrying one mature adult *P. ambloplitis* in the intestines. This record gives a new definitive host for *P. ambloplitis*. *B. sacculata,* a fluke described by Mueller and Van Cleave (1932) for Oneida Lake yellow perch, was found in small numbers in 16 of the 37 perch from Lake Opeongo and in 1 of 2 from Dixon Lake. The yellow perch of Proulx, Galeairy and Smoke Lakes yielded only half as many species of parasites as the perch from Opeongo, but the numbers of fish in the samples from the first-named lakes may have been inadequate.

SMALLMOUTH BLACK BASS, *Micropterus dolomieu* Lacépède
(Examined 61; all infested)

**Proteocephalus ambloplitis* (Leidy) (57)
Proteocephalus fluviatilis Bangham (29)
**Neascus ambloplitis* Hughes (23)
Crepidostomum cornutum (Osborn) (20)
Spinitectus carolini Holl (17)
Leptorhynchoides thecatus (Linton) (15)
Proteocephalus ambloplitis (Leidy) (12)
**Clinostomum marginatum* (Rudolphi) (6)
Proteocephalus pearsei La Rue (4)
*Microphallidae (4)
Contracaecum brachyurum (Ward and Magath) (3)
**Bothriocephalus* sp. (2)
Azygia angusticauda (Stafford) (2)
**Maritrema medium* (Van Cleave and Mueller) (2)
**Maritrema obstipum* (Van Cleave and Mueller) (1)
Gyrodactylidae (1)
**Triganodistimum* sp. (1)
**Neascus vancleavei* (Agersborg) (1)
Neoechinorhynchus cylindratus (Van Cleave) (1)
Capillaria sp. (1)
**Agamonema* sp. (1)

With the aid of creel-census workers smallmouth black bass were obtained from the following lakes: 11 from Smoke, 18 from Opeongo, 8 from Rock, 4 from Cache, 3 from Whitefish, 3 from Rain, and 14 from Galeairy. Smallmouth black bass are not native to the lakes in this region. Smallmouth black bass were not found in Proulx and Dixon Lakes and cysts of the bass tapeworm, *P. ambloplitis* were not encountered in any fish from these lakes. In many of the smallmouth

bass the visceral organs contained so many adhesions due to cysts of *P. ambloplitis* that the organs could be separated only with great difficulty. Often the surfaces of the liver and gonads were covered with cysts containing these larval cestodes. Damage by this cestode was greater than the writer ever has observed. Among the many persons who have recorded damage to the host by this larval stage are Rich (1923), Moore (1926), Bangham (1925, 1928, 1934), Hunter (1928), Hunter and Hunter (1930, 1931), Bangham and Hunter (1939), and Venard (1940). Adults of *P. ambloplitis* were obtained from 12 smallmouth black bass taken from Smoke, Opeongo, Rock, Rain and Galeairy Lakes. In smallmouth black bass from each of the lakes from which specimens were examined another species of cestode was obtained from the intestinal tract of the host. This form, *P. fluviatilis*, has but one stage in the fish. It has been reported previously only from stream populations of rock bass, smallmouth black bass, largemouth black bass, and spotted bass (Bangham 1925, 1934, and Hunter and Hunter 1931). The life cycle of this cestode is unknown.

Flesh cysts of *N. ambloplitis* were secured from 18 of the bass but not all could be examined for this parasite as only the gills and visceral organs were supplied for about one-half of the smallmouth black bass studied. Four smallmouth black bass from Opeongo Lake had larval flukes belonging to the family Microphallidae. The adults are parasites of wading birds and mammals (Van Cleave and Mueller 1932). The intermediate host is probably a crayfish. Other forms in this family have the metacercaria borne by Crustacea and all of the infested fish carried crayfish remains in their digestive tracts. *M. medium* and *M. obstipum* both were taken from the Smallmouth black bass. It appears that they may be varieties of a single species. Another member of this family was secured which was more immature. The intestinal crura were longer than in the *Maritrema* sp., and the gonads were less developed. The same or a very similar form was taken from yellow perch and ling. Sixteen of the species listed for the smallmouth black bass were observed on specimens from Lake Opeongo. Smallmouth black bass of Rock Lake carried 8 species, and those from Long Lake 10 species, while none of the smallmouth black bass from other localities had more than 5 different species of parasites.

COMMON SUNFISH, *Lepomis gibbosus* (Linnaeus)
(Examined 62; all infested)

**Neascus ambloplitis* Hughes (42)
Gyrodactylidae (39)
**Proteocephalus ambloplitis* (Leidy) (29)
Crepidostomum cooperi Hopkins (26)
**Neascus vancleavei* Agersborg (21)
**Clinostomum marginatum* (Rudolphi) (20)
Spinitectus carolini Holl (18)

Crepidostomum cornutum (Osborn) (12)
**Leptorhynchoides thecatus* (Linton) (8)
Rhabdochona sp. (5)
**Agamonema* sp. (5)
Spinitectus gracilis Ward and Magath (3)
Myxosporidia (3)
Azygia angusticauda (Stafford) (3)
**Bothriocephalus* sp. (2)
**Tetracotyle* sp. (1)
Contracaecum brachyurum (Ward and Magath) (1)
Philometra sp. (1)
Bunodera sacculata Van Cleave and Mueller (1)

Common sunfish from Algonquin Park lakes were examined in the following numbers: 28 from Opeongo, 9 from Proulx, 4 from Smoke, 10 from Dixon, and 11 from Galeairy. *N. ambloplitis* was found in 27, 7 and 8 of the Opeongo, Proulx and Galeairy Lake sunfish, respectively. Gill flukes were taken from common sunfish in all of the lakes. The gill flukes found on all species of fish were identified only to family. Encysted *L. thecatus, C. cornutum,* and *A. angusticauda* were secured only from Opeongo Lake sunfish. Only three different forms were found in four Smoke Lake specimens. All of the common sunfish from Dixon Lake had large numbers of cysts of *N. vancleavei* in their visceral organs. This parasite was found in at least one sunfish in each of the other lakes. *C. marginatum* was taken from the flesh or was found encysted in the gill cavity of fish from all locations except Smoke Lake.

LING OR BURBOT, *Lota maculosa* (LeSueur)
(Examined 14; all infested)

Abothrium crassum (Bloch) (14)
Ergasilus caeruleus Wilson (14)
Haplonema hammulatum Moulton (4)
Leptorhynchoides thecatus (Linton) (4)
Hepaticola bakeri Mueller and Van Cleave (3)
*Microphallidae (1)

All of these fish were secured from Lake Opeongo.

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THE AVAILABILITY OF SMALLMOUTH BLACK BASS, *MICROPTERUS DOLOMIEU* LACÉPÈDE, IN LAKES OF ALGONQUIN PARK, ONTARIO

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ABSTRACT

The relationship between the availability, as measured by the number of fish caught per 100 boat hours fishing, and the average size of the lake trout caught as shown by Fry (1939), has its counterpart in smallmouth black bass populations and may be used to classify different fisheries. The peak availability of approximately 300 bass per 100 boat hours falls between 11 and 12 inches, whereas the availability between 13 and 14 inches is around 150 captures per 100 boat hours. The availability of both the legal smallmouth black bass and those caught below 10 inches is highest where the average length of the bass caught is small. The total annual removal in pounds per acre in certain Algonquin Park lakes has been tabulated.

INTRODUCTION

In order to understand different fisheries it is essential that they be classified. It has been found possible to classify the lake trout (*Cristromer n. namaycush*) fishing in Algonquin Park lakes according to a method used by Fry (1939a, 1939b) by plotting the average size of the fish captured in each lake against the catch per unit effort for that lake. The present paper is presented to show that smallmouth black bass fisheries may be classified in the same manner. The relationship between the average size and catch per unit effort gives a profile of all possible angling conditions; a complete picture of the wide variation in the size of the fish and ease of capture in these lakes. Such a classification makes possible a comparison of fishing in different lakes during the same period and also a comparison of fishing in the same lake over a long period of time. With such information at hand it is possible to ascertain whether a lake is being maintained at a productive or a depleted state with respect to fishing.

THE RELATIONSHIP OF SIZE OF LAKE TROUT TO POPULATION DENSITY

The relationship between the ease of capture and the average length of the trout caught in different lakes as shown in Figure 1 has been modified by adding data for 1939 to those of Fry (1939) considered data for 1936-1938. Since this graph contains data for 4 years, the same lake may be represented by more than one point due to changes in fishing intensity from one year to another. It may be noted that the data from all the lakes are bounded by a curve which begins at a

low value, reaches 440 trout per 100 boat hours at an average length just under 16 inches and decreases rather rapidly to 75 trout per 100 hours, when the average length of the fish caught is 24 inches. The relationship between average length and availability is not one of simple proportion but there may be a wide range in the ease of capture of fish of any given average size. This range is most marked in those lakes where the average length of lake trout is small. Lakes in which the average lengths lies between 14 and 16 inches may provide the best fishing or practically none at all. Lakes in which the fish average 18 inches in length may offer moderately good fishing or none at all.

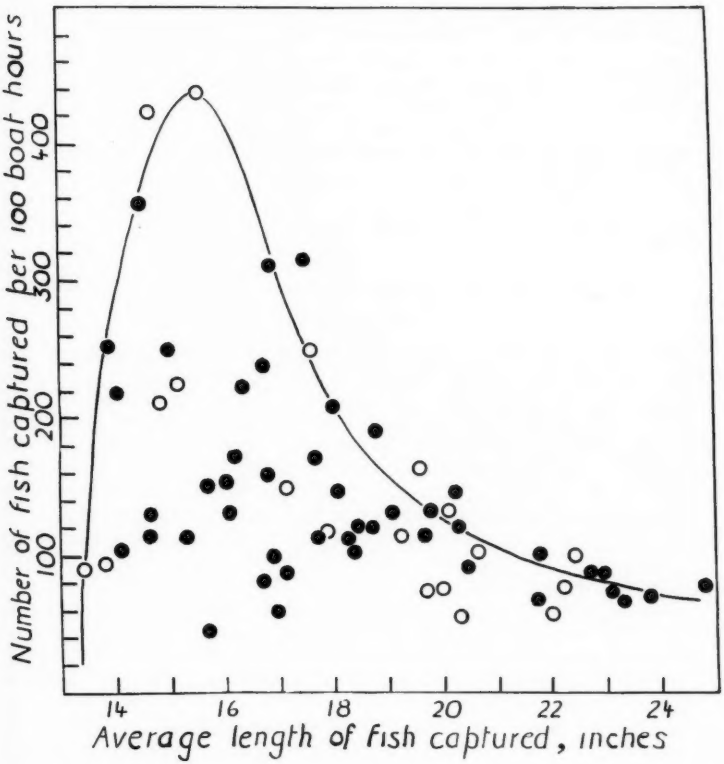

Figure 1.—The relationship between catch per unit of effort and average size of lake trout caught in lakes of Algonquin Park, 1936-1939.

Although it is possible in some lakes to have an increasing density of trout as the average size decreases down to about 16 inches, this is not true of all lakes. In many lakes the density of the population begins to decline when the average size of the trout captured falls below 18 inches. The explanation of this decline may be found in the size at which the lake trout mature, which varies from 13 to 18 inches in different lakes. It has been found, for example, in lakes where the trout mature at about 18 inches in length that the percentage of immature fish in the angler's catches increases as the size of fish decreases and the availability decreases. If the average length falls as low as 18 inches, the availability will fall almost to zero since immature fish would make up the greatest proportion of the population and sufficient reproduction could not take place. Only in lakes where the average length is approximately 16 inches and the length at maturity is about 14 inches, can the maximum catch of 440 trout per 100 hours be obtained. Again, if the average length in those lakes decreases from 16 to 14 inches the availability also falls to a low figure while the percentage of immature trout in the catches increases greatly. The decline in the availability of fish below 14 inches also is related to the fact that lake trout under 13 inches seldom take the bait. The peak availability at each size is found where abundant reproduction is taking place and the percentage of immature fish in the catches is low.

The Relationship of Size of Smallmouth Black Bass to Population Density

Having shown that a relationship exists between the density of lake trout populations and the size of the individuals of those populations, it may next be shown how a similar relationship holds for the smallmouth black bass. The angling data for bass lakes is shown in Table 1. The smallmouth black bass lakes in Algonquin Park have been classified in the same manner as the trout lakes by plotting the average length of the fish in each lake against the catch per unit effort. When presented in this manner a strikingly similar picture is obtained (Fig. 2). The graph includes 1936-1939 data, the name of each lake being indicated above the corresponding point. The following similarities with the conditions observed for lake trout may be noted.

The catch per unit effort for smallmouth black bass rises sharply from a low value at 10½ inches to 275 fish per 100 hours at 11 inches. From this peak the catch falls to 130 fish per 100 hours for lakes in which the average size of the smallmouth rock bass caught is 14 inches. When the average length falls as low as 10½ inches as indicated by the data for Provoking Lake, the condition of the fishing apparently corresponds to that found for lake trout when the average length falls below 16 inches. Unfortunately no data have been gathered concerning the fecundity of smallmouth black bass in angler's catches, but a lake in such a state as Provoking probably has a large percentage of

Table 1.—The annual catch of smallmouth black bass in lakes of Algonquin Park, 1937-1939

Lake	Year	Number caught	Average length (inches)	Availability	
				10 inches and over (legal)	Below 10 inches (illegal)
Cache[1]	1939	754	11.3	154	400
	1938	863	11.4	180	313
	1937	403	11.3	152	244
Tanamakoon[1]	1939	57	12.0	204	223
	1938	100	11.6	256	256
	1937	38	11.1	185	230
Canisbay[1]	1938	78	12.0	222	222
Smoke	193	215	13.0	116	107
	1938	34	13.3	98	83
Canoe	1939	27	12.5	150	94
Rain	1939	80	12.5	95	....
Provoking	1939	26	10.5	66	85
Rock	1939	118	11.5	118	71
	1938	22	13.0	152	100
Whitefish	1939	37	13.3	104	84
	1938	41	14.3	80	....
Opeongo[1]	1939	270	12.9	115	....
	1938	731	13.5	144	....
	1937	628	13.0	145	....
Wright	1939	59	14.3	116	....
	1938	22	13.7	86	....
Booth	1939	51	14.0	127	....
	1938	133	14.9	110	....

[1]Designates lakes in which the number of fish caught approximates the total annual removal.

immature fish since natural spawning in this lake appears to be failing. In lakes where the smallmouth black bass average 12 inches or more in length they are moderately easy to catch, but similar to the corresponding size for lake trout, the fishing is never as good as it is in lakes where the average length lies between 11 inches and 12 inches. It is not yet known at what length smallmouth black bass mature in the different lakes in Algonquin Park or how the length at maturity may be correlated with the readiness of capture. Apparently the situation parallels that of the lake trout in that large smallmouth black bass influence density of their own populations.

Further insight into this limiting effect of large fish on the population density may be obtained by measuring the availability of the fish smaller than those normally removed by angling. As previously stated trout less than 13 inches in length rarely take the bait whereas the smallmouth black bass under 10 inches long are caught regularly by anglers. In Ontario, all smallmouth black bass caught that are less than 10 inches long must be returned to the water. The availability of illegal fish for different lakes has been determined since the

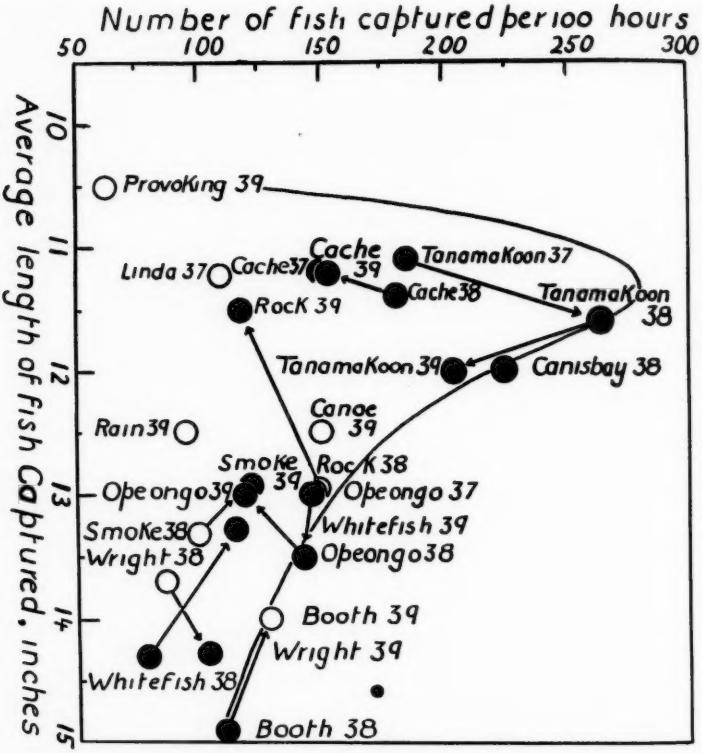

Figure 2.—The relationship between catch per unit of effort and average size of smallmouth black bass caught in lakes of Algonquin Park.

anglers reported the number caught and returned to the water. The smallmouth black bass over 10 inches long will subsequently be referred to as "legal fish."

Small lake trout are not taken by angling, but information about them has been obtained by gill netting. The evidence obtained in this manner from certain lakes where the average length of the lake trout caught lies between 14 and 16 inches in length, has shown that lake trout below 13 inches not only are present in considerable numbers, but that they are actually more numerous at this size than are the fish from 14 to 16 inches in length even though very few are caught by angling. On the other hand, gill netting in lakes where the lake trout

caught are over 18 inches in length shows an absence of small fish. The smallmouth black bass data present parallel evidence. The fishing characteristics of bass lakes in Algonquin Park are indicated in Table 1. It may be noted that the highest availability of smallmouth black

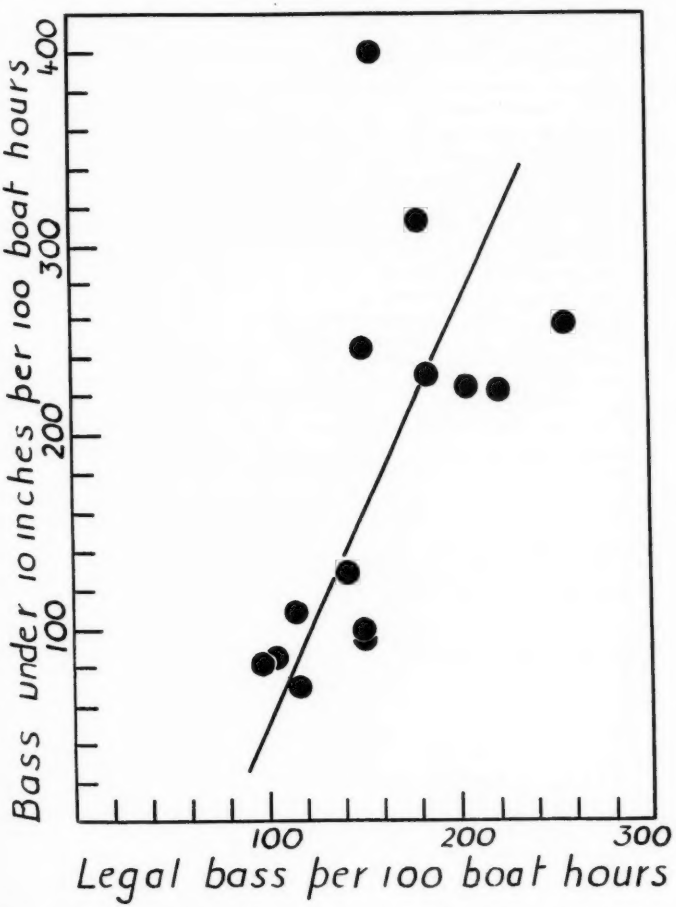

Figure 3.—The relationship between the catch per unit of effort of smallmouth black bass longer than 10 inches with the catch per unit of effort of smallmouth black bass 10 inches and shorter.

bass is found in Cache and Tanamakoon Lakes where the average length of the fish caught lies between 11 and 12 inches. In these two lakes the availability of smallmouth black bass under 10 inches usually is greater than that of the legal fish. It may also be noted that in Smoke, Canoe, and Whitefish Lakes, where the average size of the bass captured lies between 12½ and 14 inches, the bass under 10 inches in length are more difficult to catch than those over 10 inches.

The relationship between the ease of capture of the legal smallmouth black bass and those under 10 inches that are captured may be shown by plotting the availability of these two size groups (Fig. 3). The slope of the straight line fitted to the plots is such that for legal bass with an availability of 100 per 100 hours, there is an availability of about 50 per 100 boat hours for fish under 10 inches. An availability of 200 legal smallmouth black bass per 100 hours corresponds to an availability of about 260 fish per 100 hours below 10 inches. There is a statistically significant positive correlation of 0.52 between the availability of the two size groups.

Conclusions

The evidence presented dealing with capture of small fish in relation to the presence of larger fish in the same population indicates that such fish are present in maximal abundance only when the average size of the lake trout and small mouth black bass removed by angling is between 15 and 17 inches and 11 and 12 inches, respectively. When the average lengths of the two species are greater than these ranges, the abundance of lake trout under 13 inches and smallmouth black bass under 10 inches is limited. That is, the large fish of both species apparently limit the density of their own populations.

The smallmouth black bass fisheries in Algonquin Park thus present a picture that is similar to that of the lake trout. The population den-

Table 2.—The annual removal of smallmouth black bass from certain lakes during the years 1937-1939

Lake	Year	Area of lake (acres)	Average length of fish (inches)	Number removed	Pounds removed	Pounds per acre removed
Opeongo	1939	15,000	12.9	270	380	0.025
	1938	.....	13.5	731	1,190	0.078
	1937	.....	13.0	628	900	0.058
Smoke	1939	1,500	13.0	215	218	0.140
Canisbay	1938	350	12.0	78	89	0.250
Tanamakoon	1939	230	12.0	57	65	0.280
	1938	.....	11.6	100	103	0.450
	1937	.....	11.1	38	33	0.140
Cache	1939	610	11.2	754	680	1.120
	1938	.....	11.4	863	837	1.370
	1937	.....	11.3	403	378	0.620

sity in any lake is affected by the size of the fish caught in that lake. It is probable that the smallmouth black bass lakes present the same characteristics as the lake trout lakes with respect to the annual removal that they can support. That is, where the fish caught are small, a greater annual removal should be possible than where the fish caught are large, since denser populations are present in the lakes with small fish. The limitations of this statement have been discussed previously. The annual removal in pounds per acre for the more heavily fished bass lakes in the Park is shown in Table 2. It is interesting to note that there is a rough relationship between the area of the lake and the average length of the bass present in it. It may also be noted that lakes in which the average length of the fish caught is small have the highest annual removal in pounds per acre. It is thus quite probable that lakes such as Cache where the average length is around 11 inches tolerate a higher removal than lakes such as Opeongo, where the average length is around 13 inches. However, it must be mentioned that Cache lake is the only lake listed in which the annual removal approaches the maximum that can be tolerated, since this lake lies well below the boundary curve of maximum availability in Figure 2.

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ARTIFICIAL FEEDING OF WHITEFISH FRY

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ABSTRACT

Through experiments conducted at the Winnipegosis and Dauphin River hatcheries in Manitoba, it has been determined that the artificial feeding of whitefish fry (*Coregonus clupeaformis*) is of value in those localities where the eggs hatch early in the spring and fry must otherwise be planted while the lakes are covered with ice. At that time the existence of an adequate supply of food organisms is uncertain. Various artificial foods were tried in the experiments but the most satisfactory results were obtained with (1) natural plankton (principally *Daphnia pulex*), and ground beef heart, and (2) natural plankton alone. During the hatching period three successive batches of fry may be held in tanks and fed for a 10-day period before they are released. Fry gain in length, weight and viability during the period of artificial feeding and are better fitted for survival in the natural environment. Through the delay in planting, the supply of available natural food and the temperature of the water in the lake environment are enabled to become more favorable by the time the fry are ready to be transferred from the tanks to the lake.

The artificial feeding of whitefish fry (*Coregonus clupeaformis*) at the Winnipegosis Hatchery was recommended by Dr. A. D. Bajkov prior to 1930, in order to avoid the necessity of planting early-hatched whitefish through holes in the ice. The venture was advisable because of the uncertain natural food supply for whitefish fry so far in advance of the vernal upturn in plankton abundance that usually does not occur until after the lake is free of ice and the water temperature begins to rise.

Early experiments in feeding whitefish fry were conducted by retaining the fry in crates constructed with sides of fine-meshed screen which were submerged in the harbor adjacent to the hatchery. The food consisted of natural plankton obtained with tow nets from the adjacent lake waters. Results were very unsatisfactory since only 2 to 4 per cent of the fry had survived on August 15.

A large outdoor tank, 30 feet long, 10 feet wide and 3 feet deep, was constructed and used for the first time in 1932. Approximately 1 million fry were placed in the tank after hatching and were fed with ground beef liver until July 1. About 200,000 fingerlings which had survived were then transported to and planted in Lake Winnipegosis, about 60 miles north of the hatchery. The Winnipegosis Hatchery was closed in 1932 and no further feeding experiments were conducted there.

A new whitefish hatchery was constructed at Dauphin River in 1936. Two whitefish rearing tanks, 30 feet long, 10 feet wide and 3 feet deep were constructed in time to receive the fry hatched during the spring of 1937. Nearly 5 million advanced whitefish fry and fingerlings were reared in the tanks. The water cooling system installed in the hatchery made it possible to retard the incubation and hatching of the eggs so that two batches of fry were reared in each tank during the same season. The diet that year consisted of ground beef liver in addition to the natural food organisms contained in the river water which circulated through the tanks at a rate of 8 to 12 gallons per minute.

During the following year, 1938, feeding experiments were conducted by David Hinks, biologist of the Department. For his work eight small experimental tanks were constructed, each provided with a separate water supply and overflow outlet. A total of 1,000 whitefish fry were placed in each tank and a different diet was supplied to each group for a period of 3 weeks. The various foods used were as follows:

1. Ground beef liver
2. Natural plankton (principally *Daphnia pulex*)
3. Ground clam meats
4. Ground clam meats and beef liver
5. Ground dried sucker eggs
6. Ground fish
7. Ground fish and beef liver
8. Powdered milk and ground beef liver

The most satisfactory results were obtained with the natural plankton and 20 per cent of the initial number of fry survived. Ground beef liver yielded the second best results—a survival of 4.5 per cent. The other diets were unsatisfactory.

A shallow pond was constructed during 1939 which was fertilized with sheep manure in an attempt to cultivate a supply of *Daphnia* for feeding whitefish fry. Since the spring of 1939 was both cold and dry *Daphnia* were difficult to find, but by the end of the whitefish feeding season the pond was producing a fairly good crop. During the spring of 1940 exhaust steam from the hatchery was piped to, and along one side of, the pond and a good population of *Daphnia* was available by the time the whitefish fry began to hatch.

One tank of fry was fed with ground beef heart during 1939 and a survival of 33 per cent, the best for the season, was obtained.

Present plans for next season are to hold whitefish fry in tanks and feed them for 10 days with *Daphnia* and ground beef heart before planting them in the lake. Ten days of artificial feeding increases the size and viability of the fry greatly and they are much more active at the end of the feeding period than immediately after hatching. The

short period of artificial feeding, therefore, places the fry in a better condition to feed naturally and to survive in the lake environment. Three batches of fry can be held and fed in each of the tanks during the 30-day period over which the eggs hatch.

A heavy loss of fry in the tanks occurs during the time when bulldog flies (*Tabanus* sp.) are emerging. Various pollens from trees, shrubs and flowers are rising in the air at this time, also, and settle on the surface of the water in the tanks. Whether the loss of fry is associated with the emergence of tabanids, with the consumption of pollen, or with the rapid increase in water temperature that is coincident, has not been determined. By planting the young whitefish before June 20 in an average year the heavy losses have been avoided largely.

THE LENGTH OF THE GROWING SEASON OF LARGEMOUTH AND SMALLMOUTH BLACK BASS IN NORRIS RESERVOIR, TENNESSEE[1]

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ABSTRACT

The length of the growing season of largemouth black bass and smallmouth black bass in Norris Reservoir for 1939 has been calculated to be not more than 4 months. The season's growth in both species of bass began after late May. The largemouth black bass had completed their growth by the early part of October, and the smallmouth black bass by the latter part of September. This 4-month growing period corresponded to that during which the water in the lake was 75° F. or above, and was much shorter than the agricultural growing season of 7 months.

The more rapid growth of fishes in southern waters, as compared to northern waters, generally has been attributed to the longer growing season in the South, but no comparative data are available on the length of the growing season of fish in the two areas. This study is an attempt to determine the approximate growing season of the black basses in a southern water.

Bennett (1937) compared the growth of Wisconsin largemouth black bass (*Huro salmoides*) with the growth of largemouth black bass from Louisiana and found that the southern fishes grew much more rapidly than those in the North. Schoffman (1940) compared the growth of the white crappie (*Pomoxis annularis*) from Reelfoot Lake, Tennessee, and from Illinois, and found that the fish from the former locality made a slightly more rapid growth than did those from the latter. Both Bennett and Schoffman attributed the more rapid growth of the southern fishes to a longer growing season. However, both authors refer to the length of the agricultural growing season. The time of annulus formation was determined for the white crappie in the waters of Illinois by Hansen (1937), but the end of the growing season was not noted and, therefore, the length of the growing season was not determined. Hile (1936) made calculations of the growth of the cisco (*Leucichthys artedi*) in northern Wisconsin and discovered that growth in one lake had been completed soon after the collection of the scale samples in July. In another lake the season's growth had not been completed until late September. Hile did not determine the time of annulus formation, although he assumed that growth did not begin until after the ice had disappeared from the lakes in May. Here again the actual length of the growing season was not deter-

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mined. Hansen's work suggests that the growing period varied decidedly for individual fish of the same species within the same body of water, while Hile's study indicates that the growing period for one species may differ widely in several waters in the same general vicinity.

The determination of the approximate length of the growing season of largemouth and smallmouth black bass in Norris Reservoir is based on a study of scale samples from 282 fish taken in May, 1939, 216 taken in September and October, 1939, and 240 largemouth and smallmouth black bass taken in April and May, 1940. Fish were identified and scale samples taken by biologists. Scales submitted by sportsmen were discarded because of the difficulty many fishermen have in differentiating between the three species of black bass in Norris Reservoir: Largemouth black bass, *Huro salmoides* (Lacépède); smallmouth bass, *Micropterus dolemieu* Lacépède; and spotted or Kentucky bass, *Micropterus punctulatus* (Rafinesque).[2]

Scales were collected by the writer in the fall of 1939 from fish brought to the docks by fishermen. Additional scale samples were taken in the spring of 1940 from fish which were tagged and released. The sex of these bass was not determined. However, Eschmeyer (1940) noted that male and female bass taken in the spring of 1939 were growing at the same rate.

The largemouth and smallmouth black bass caught during the spring of 1939 and 1940 were taken with artificial bait under the immediate supervision of T.V.A. biologists. The fish caught in the fall of 1939 were taken on hook and lin with both natural and artificial baits. A small number of fish was obtained from sinkholes. Individuals procured in this manner have been considered separately below. Except for this latter group, the method of sampling was similar for all fish.

The scales were mounted in a gelatin-glycerine preparation according to the formula suggested by Van Oosten (1929), and were studied on a microprojection machine patterned after the one described by Van Oosten, Deason, and Jobes (1934).

According to Eschmeyer (1940) the adult bass in 1939 had not formed an annulus by late May.

A comparison of the lengths of largemouth bass caught in October, 1939, and in the spring of 1940 (Table 1), shows that the fish taken

Table 1.—Comparison of lengths of largemouth black bass in October, 1939, and in the spring of 1940

Age group	October, 1939		Spring, 1940	
	Number of fish	Total length (millimeters)	Number of fish	Total length (millimeters)
III	73	380	109	388
II	64	314	72	323

[2]The writer wishes to express his appreciation to Dr. A. H. Wiebe, who made this study possible and assisted in the preparation of the manuscript, and to Dr. R. W. Eschmeyer, who suggested the problem and assisted in interpreting scale readings.

in the spring were slightly longer than those taken in the preceding fall. The difference in the lengths of the two groups was slight and for all practical purposes it was insignificant. Practically all of the growth for 1939 had been completed by the early part of October. Since 58 per cent of the scales had been taken by October 8, and 80 per cent by October 15, the growing season for the largemouth black bass must have extended over the period from late May until early October—about 4 months. None of the fish caught during April and May, 1940, had formed an annulus.

The smallmouth black bass, like the largemouth, had not begun to grow before June, 1939. A comparison of the lengths of smallmouth bass caught in September and October, 1939, and the spring of 1940 (Table 2) indicates that growth had almost ceased during September.

Table 2.—Comparison of lengths of smallmouth black bass in September and October, 1939, and in the spring of 1940

Age group	September, 1939		October, 1939		Spring, 1940	
	Number of fish	Total length (millimeters)	Number of fish	Total length (millimeters)	Number of fish	Total length (millimeters)
III	34	402	26	406	37	405
II	....	.....	19	324	22	327

Of the 34 fish in the September collections, however, 53 per cent were taken by September 15. A comparison of the lengths of the young of the year (smallmouth) taken from sinkholes during September and October, 1939 (Table 3) also shows that no growth had occurred after the latter part of September. The growing season for the smallmouth black bass during 1939 was therefore about 3½ months. One would expect the smallmouth black bass, a species that prefers cooler water, to continue to grow after the largemouth black bass had stopped growing and hence that the smallmouth would have a longer growing season. If this expectation is valid, the growing season of the largemouth black bass should be somewhat less than the 4 months mentioned above.

Table 3.—Comparison of lengths of smallmouth black bass taken from sinkholes in September and October, 1939

Age group	September		October	
	Number of fish	Total length (millimeters)	Number of fish	Total length (millimeters)
0	20	134	23	134

The 1939 growing season may have been shorter than normal due to a cool, late spring. The U. S. Weather Bureau reported that March was a moderately warm month, but April temperatures were somewhat below normal with frequent changes from warm to cold. There

were several heavy frosts during the first half of May, but temperatures during the latter half were above normal.

Although the spring began normally, the cool weather during April and the first half of May prevented the lake from warming up until quite late in the season. Most of the bass spawned during the protracted hot weather of May 18 to 31.

Temperature observations were made on Norris Reservoir during 1939. The approximate date the water reached 65° F. (Figure 1) agreed closely with the observed spawning date, while the period during which the temperatures at the 10-foot depth were 75° F. or above corresponded with the period of growth of the bass.

The 1939 agricultural growing season for Knoxville, Tennessee, 19 miles south of Norris Reservoir and at about the same altitude, was given by the U. S. Weather Bureau as beginning on April 8 and ending November 1. When this period of almost 7 months is compared with the 4 months of the bass growing season (Figure 1), a large discrepancy is obvious. It is evident that the growing season of crops is substantially longer than the growing season of fishes.

The preceding discussion shows that the growing season of black bass in Norris Lake in 1939 was shorter than might be expected, and that the period of growth of the bass was much shorter than the growing season of agricultural crops. While the exact dates have not been determined, this study shows the growing period to be not longer than 4 months. The monthly increments have not been determined, but are being studied for the 1940 growing season.

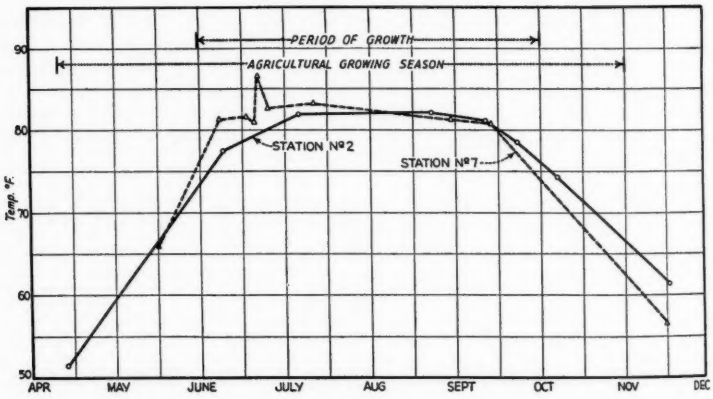

Figure 1.—A comparison of the growing periods of the black basses and of agricultural crops, with a graph of water temperatures at two stations in Norris Reservoir.

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FISHERY COOPERATIVE ASSOCIATIONS IN RELATION TO CONSERVATION AND ORDERLY MARKETING

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ABSTRACT

Fishery cooperative marketing associations are democratically organized economic enterprises conducted for the mutual welfare of their members. They may aid in various phases of conservation. Cooperatives may assist in preserving fish populations in the interests of sustained yield through self-imposed regulations of gear, season, sizes of fish captured, and of other aspects of fishing activity. In these matters, however, they cannot entirely supplant regulation by public authority.

The greatest contributions of cooperatives to conservation are in conserving the catch by efficient and orderly marketing. In the United States they market nearly 1 billion pounds of fish worth about 9 million dollars. In marketing the catch of members and by their influence on marketing agencies generally, cooperative associations may eliminate wasteful practices and insure the highest utility for our fishery products. Such activities benefit the consuming public as well as the fishermen and the other elements of the fishery industry.

A cooperative is an economic enterprise conducted on a democratic basis for the mutual welfare of a group. The benefits are distributed according to the volume of business between individual members and the organization and not on the basis of capital investment. It is a non-profit enterprise and all of its functions are performed on an "at cost" basis. A cooperative is controlled by its members, usually having one vote each irrespective of the investment of each member. Such an organization increases the influence of the individual members of any like type of association.

Fishery cooperatives may take an active part in two phases of conservation of our fishery resources. First, they may assist in insuring the sustained yield of our fisheries by providing a channel through which a large number of fishermen may act together in adopting and supervising measures which will conserve fish populations. Thus fishermen united for certain economic activities can utilize the same organizations for group action along other lines and even influence fishermen outside the movement. They may agree on size limits of fish taken, or mesh sizes for nets, on intensity of fishing effort, or other conservation measures. Thus, voluntary action may supplement or replace regulation which must otherwise be undertaken by public authority.

However, the pressures of economic forces under our conditions of free enterprise may be mitigated by cooperative activity, they cannot be avoided. When a fishery is profitable, more people enter the industry. If more enter the fishery, or intensity of fishing effort increases, the increased fishing lowers the returns of all or most mem-

bers of the fishery. In any event there tends to be a cycle with a point at which some members of the industry are forced out.

Cooperatives may alleviate some of the more destructive effects of competition between fishermen and of competition in fish marketing as it affects the fisherman. However, the industry must look to public authority as the leading force in conserving the fish populations which form the basis of commerce in fishery products. The public interest in this phase of fishery conservation is so great that it will undoubtedly receive full recognition.

The other phases of conservation in which cooperatives may play a leading part are in the efficient utilization and orderly marketing of the catch and the resultant products and byproducts. Conservation continues to be of prime importance after the fish are caught, for it is only as the products of the fishery are utilized by our people that this great natural resource contributes to economic welfare. To insure that the catch has the greatest possible utility, the marketing system must operate with maximum efficiency. Waste must be kept at a minimum and distribution must be universal, timely, and as inexpensive as is consistent with the other aims. Surplus and scarcity must be avoided and a variety of wholesome fish and shellfish must be available at reasonable prices and in suitable form wherever and whenever economic conditions warrant.

The greater the efficiency of the marketing process, the more the public and the producer gain. When the cost of processing and distribution is maintained at the optimum level, the consumer pays less for his fish and the fisherman is paid more. Cooperatives are uniquely adapted to increasing the efficiency of the marketing process.

The ways in which cooperatives can confer benefits are based on the combined power of fishermen when buying and selling together. In this field, the cooperative may set the standard of efficiency. It is not necessary that the cooperative handle all the trade in a particular line. Private competition must make as great returns to the fishermen as the cooperative in order to obtain business. Thus the efficient cooperative may serve as a yardstick by which the services of other agencies may be measured.

Where the catch of a large number of fishermen is concentrated in the hands of one cooperative, the bargaining power of the individual fisherman is multiplied. Otherwise the seller who is in the weakest bargaining position, or the most efficient fisherman who produces at the lowest cost, may set the price at a point which is unprofitable to most of those engaged in that fishery. A fisherman who is hard pressed financially and must have some money, no matter how little, may break the market to a point below the price justified by the general relations of supply and demand. Where there is no organization to unify the bargaining power of the producer, the bargaining power of the buyer may be so great as to lower prices unjustifiably and so injure the whole fishery. The cooperative must, of course, meet the

difficulties caused by weak sellers outside the association. However, if the cooperative controls the bulk of the supply, the buyers must come to it eventually when the smaller, uncontrolled supplies have been absorbed.

The large supply under unified control makes for efficiency and gives an advantage in trading because purchasers can obtain large quantities with the minimum of effort. They need contact but one agency in a given place. There is no necessity for the expensive process of getting in touch with a large number of producers in many different localities. If the cooperative or a federation of cooperatives covers a large enough territory, it may draw on certain areas that are in full production when there is a shortage in other regions.

The organization with a large volume of sales can afford to keep in touch with a variety of outlets. Gluts are alleviated by the possibility of entering distant markets if local or nearby markets are overloaded. Thus the markets may be fed according to demand. The individual fisherman operating alone often can do no more than ship on consignment and run his chance of getting only a freight bill in return.

A cooperative handling a large quantity of fish can grade and standardize its products, without unduly increasing costs. This procedure helps to establish a reputation for goods of specified qualities such as size, weight, and freshness and may insure better demand and better prices. Buyers can bid closer to the prices they are justified in offering if they do not have to lower their bids to allow for the goods being inferior to their expectations. The cooperative may establish a brand or trade mark which aids in wholesale or even retail sales. Or it may utilize a state brand or grade label such as that under which Virginia salt herring is marketed.

One way of avoiding glutted markets is for the cooperative to store the fish during periods of abundance for sale during periods of scarcity. Such operations must, of course, be based on a thorough knowledge of marketing conditions and a close study of the economic forces in operation.

Other forms of processing beside placing in cold storage, such as canning or curing, also may be performed by the cooperative. By thus carrying the product closer to the consumer by processing, packaging, smoking or salting, control of the commodity is exercised through a greater part of the marketing process. Moreover, gains may be made through efficient processing which correspond with profits made by private operators. These may add to the producers' returns in terms of higher prices for the raw fish. Examples of this activity are salmon and oyster canning associations and crab meat packing cooperatives on the Pacific Coast. Mild curing of salmon also is performed cooperatively.

Cooperative concentration of marketing operations frees the fisherman from dependence on the local market. If local prices are not as high as general price levels warrant, the cooperative can ship to cen-

tral markets or attract buyers from a distance, by reason of volume. Two cooperatives in Michigan and Minnesota are trucking their fish to central markets. In Vinalhaven, Maine, the members of a cooperative felt that the local lobster buyers were not offering a price justified by central market conditions. By combining their catches they concentrated a sufficient volume to attract an outside buyer who was willing to pay a higher price.

Cooperative associations can also act as purchasing agents for their members and some are set up solely for this purpose, as for example, a supply cooperative conducted by New Jersey oyster growers. By combining their individual demands for gear, motor fuel, and other items of equipment, fishermen can purchase in large quantities and conduct their own retailing operations so as to obtain them at minimum cost. Part of the savings made in cost of equipment and supplies purchased through the cooperative may be reflected in lower prices of fishery products to the consumer.

In general, it may be said that whatever improvements in economic techniques are open to enlightened management may be pursued by cooperatives. Whatever gains are to be made by concentration of control under adequate safeguards are open to a forceful cooperative movement. Benefits from cooperative activity accrue to the consuming public as well as to the fishermen and aid conservation.

Cooperative associations among fishermen of the United States, according to a survey made in 1936, marketed over 1 billion pounds of fish valued at about 9 million dollars. This business constituted about 24 per cent, by weight, of the fish produced by our fisheries and about 10 per cent of their first-sale value. The bulk of this volume of cooperative business was made up of Pacific Coast species marketed through collective bargaining arrangements with canners and other processors. Reports from some 60 commercial and semi-commercial cooperatives of various types indicated that they represented some 12,500 fishermen who were either members of the cooperatives or personnel on members' vessels. These cooperatives had investments in plants, equipment, and other facilities amounting to about 5 million dollars, while their members had about 24 million dollars invested in boats and gear.

As new cooperatives are organized, they are for the most part the outgrowth of sporadic efforts and have the peculiarities of the local situation stamped in their framework. One of the functions of the Fish and Wildlife Service is to serve as a clearing house for information and advice for cooperative enterprises among fishermen, so that greater uniformity may be attained and so that new organizations may be advised concerning the principles and practices of the ideal cooperative. It is only by such coordination, or as a more general movement toward cooperative organization may arise, that cooperation among fishermen may realize its full potentialities.

The cooperative movement in Nova Scotia which has developed with

increasing velocity during the last few years, has been widely heralded for its success in solving the economic problems of a fishery that was in an extremely depressed condition and a fishery population that was in dire want. The movement embraced other industries, particularly mining and farming, and has spread to Newfoundland, New Brunswick, and British Columbia. It has even exerted some influence in the United States, though less among fishermen than among some other groups.

The establishment of cooperative lobster canneries was an important outgrowth of the cooperative movement in this region. By marketing their catches in this way, the fishermen were able to realize higher prices than had prevailed. Other enterprises such as cooperative stores were undertaken successfully. Cooperatives which had been established earlier were carried to greater achievement along with the newer cooperatives. This movement has brought not only some material gain to the regions in which it has developed, but the courage to go further.

An ever increasing number of individual fishermen is becoming interested in cooperative organizations. It provides a means of overcoming many of the difficulties and uncertainties of individual enterprise. We may expect a pronounced increase in the number of such organizations during the next few years.

Discussion

Mr. W. C. Herrington: The reference to the concentration of catches in sufficient quantities to increase the efficiency of marketing and also distribution appears to apply particularly to scattered fisheries such as may be found along the coast of Maine. Where the fish are landed in small communities and in small quantities, the problem of transportation becomes of importance. The material has to be picked up and taken to Portland and distributed from there. It seems to me in a fishery such as that, cooperatives might serve a useful purpose. This purpose might also, I suppose, be served by capitalistic industry which would establish a pick-up system that would function in the same way. In that we have a very important question as to whether there is sufficient leadership among the fishermen to develop and operate through cooperatives or whether it is necessary to turn to some other agency which can give the proper leadership.

Mr. R. H. Fiedler: It seems to me that the commercial fishery cooperative has a great deal to offer to conservation. It is much easier to promote the development of conservation programs among groups of cooperative fishermen than it is to work with the individual fisherman. In carrying out sport fishing conservation programs we work with anglers' associations, groups, or clubs, and no doubt this would apply equally well to the commercial fishing industry.

FLUCTUATIONS IN LENGTHS AND NUMBERS OF CERTAIN SPECIES OF FISHES OVER A FIVE-YEAR PERIOD IN WHITMORE LAKE, MICHIGAN[1]

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ABSTRACT

Largemouth black bass, bluegills, and yellow and brown bullheads were taken annually in Whitmore Lake in the same manner and with the same types of legal tackle during the summers of 1934-1938. The length-frequency curves obtained yearly for each species indicate an annual increase in average lengths from 1934 to 1937 and/or 1938. Fishes spawned in the years 1931-1933 dominated between 1934 and 1936, and largemouth black bass of the 1931-1933 year classes apparently formed the principal fish predators in 1934 and 1935. In 1934 and 1935 the fry survival of all species was low, despite good hatches. Evidence indicates that the adult largemouth black bass population was low during 1936 and 1937; during these years the survival of fry of all species was high, although the hatches were seemingly no better than in previous years. The largemouth black bass hatched in 1936 and 1937 were exceedingly abundant in 1938, and unless a great reduction in their numbers occurred they might be sufficiently numerous to devour most of the fry produced by all species in the next few years. It is suggested that a predator-prey relationship may exist, and that a relationship of this type may be the source of cyclic fluctuations in abundance.

INTRODUCTION

While connected with the Institute for Fisheries Research of the Michigan Department of Conservation and the Fish Division of the Museum of Zoology of the University of Michigan I heard many statements from fishermen concerning changes, from one year to another, in the abundance and average size of game-fish and pan-fish species in certain lakes. The statement was often made that Lake "A" had provided good fishing for largemouth black bass (*Huro salmoides*), northern pike (*Esox lucius*), or wall-eyed pike (*Stizostedion vitreum vitreum*) a few years ago, but that lately fishing in this lake was very poor for these species, and that bluegills (*Lepomis macrochirus*) or yellow perch (*Perca flavescens*) were at present taken in abundance. It was stated also, that when many bass were caught a few years earlier in Lake "A," they averaged smaller in length than do the few bass which are taken at present. It was claimed further that neighboring Lake "B" had fine largemouth black bass, northern pike, or wall-eyed pike fishing this year, and that bluegill or yellow perch fishing was poor. In nearby Lake "C" fishing for all species was very poor but had been excellent for bluegills or yellow perch a few years previously.

[1]The assistance of staff members of the Michigan Institute for Fisheries Research in tabulating some of the data is acknowledged.

During the 5-year period between 1934 and 1938 I spent from early June to early September of each year at Whitmore Lake, Michigan. Throughout that period I kept rather careful records of the fish catches made by my father, a few friends, and myself. At the end of 3 years I realized that the abundance and average sizes of the game and pan fishes of Whitmore Lake did not remain constant, and that the changes in the abundance and the average lengths of fishes reported for other Michigan lakes were occurring also at Whitmore Lake. At the end of the 5-year period the accumulated records and data appeared worthy of publication.

Description of Whitmore Lake

Whitmore Lake is located in the pot-hole lake country of southern Michigan, about 12 miles north of Ann Arbor, on the Washtenaw-Livingston county line. The lake is roughly pear-shaped, is slightly over 1.5 miles in greatest length, and has a surface area of approximately 600 acres. There is one small area of less than 7 acres over 60 feet in depth and with a maximum depth of 69 feet; two other small depressions are present of over 35 feet in depth. More than 60 per cent of the lake is less than 20 feet in depth. Before 1937 the lake contained no visible inlet or outlet. Extending over a period of several years there was an extreme variation of possibly 5 feet in water level. The drought conditions of 1930 to 1935 caused a lowering of the lake level to almost 4 feet below high stage. Since the lowering had occurred slowly, aquatic and land vegetation had had time to adjust properly to the changing conditions. In the winter of 1936-37 a Government project was completed which consisted of connecting Whitmore Lake with the Huron River system through an outlet from nearby Horseshoe Lake. In the spring of 1937 the surface level of Whitmore Lake was raised rapidly about 3 feet by means of this connection. That spring the abundant aquatic vegetation began to grow as usual. In June the plants began to die in those beds of submerged aquatics, consisting chiefly of various species of pondweeds (*Potamogeton compressus, P. amplifolius,* and others) and tape-grass (*Vallisneria spiralis*), which were in water over 15 feet in depth. Their decomposition, plus the resultant increased abundance of plankton and increased wave action (because of higher water level and fewer barriers), caused a marked turbidity in this usually clear-water lake. With the increased turbidity more and more vegetation began to die. Apparently decreased light was a factor in the death of these plants. On the warm day of August 30, 1937, the water was so cloudy from decomposing vegetation and accompanying huge quantities of plankton (particularly zooplankton) that visibility in the lake water was reduced from the normal 10 to 15 feet to only 6 inches. Increased wave action had resulted in considerable beach-wash. Instead of adding "clean, clear" water, as the residents had hoped, the additional water caused the lake to appear "more dirty," and there-

fore less desirable to swimmers and fishermen. A sharp decrease in temperature on September 4 caused a partial clearing of the water, and the accompanying high wind piled plankton along some portions of the shores to a depth of several inches. On that day I estimated that less than 10 per cent of the submerged aquatic vegetation remained alive. By the fall of 1938 adjustment to the increased water level had become apparent, but establishment of the former abundant vegetation was far from complete. One interesting result was that certain plants, such as the species of *Potamogeton,* had greatly decreased in abundance while a few others such as hornleaf (*Ceratophyllum demersum*) had held their own or actually increased. These drastic changes in this usually rather stable lake may have had considerable bearing on later fish populations.

The principal game and pan fishes were largemouth black bass, bluegills, northern pike, smallmouth black bass (*Micropterus dolomieu dolomieu*), yellow perch, brown bullhead (*Ameiurus nebulosus nebulosus*) and yellow bullhead (*Ameiurus natalis natalis*). The most important fish predator was presumably the largemouth black bass, since the smallmouth black bass and northern pike were much less numerous. The yellow perch population seemed low. The total number of all species of fishes recorded was 34. In 1933 the Michigan Department of Conservation made two experimental plantings of gizzard shad (*Dorosoma cepedianum*) with no apparent success. It is reported that since the connection of Whitmore Lake with the Huron River drainage the long-nosed gar (*Lepisosteus osseus*), carp (*Cyprinus carpio*), and black crappie (*Pomoxis nigro-maculatus*) have invaded the lake. Several thousands of largemouth black bass and bluegill fingerlings were stocked annually in the lake by the Michigan Department of Conservation.

Methods of Fishing and Recording Data

All fish were taken during the legal season with legal fishing equipment. Over 85 per cent of the catch was taken by my father and me, the remainder by a few friends who accompanied us and whose methods were similar to ours. With the exception of a slight amount of specialized fishing for fingerling largemouth black bass in 1938, fishing methods and equipment were the same throughout the 5-year period; and the same sections of the lake were fished annually for the same lengths of time. All measurements of the total length of specimens were taken to the nearest one-quarter inch. The stomach contents of over 95 per cent of the legal bass and of 50 per cent of the bluegills were subjected to gross examination. About the same length of time was spent yearly in observing fish nests and fry. Largemouth black bass and bluegill scales were saved annually from a few specimens for age determinations, and in 1935 scales were saved and read from 120 bass of lengths over 7 inches. Further details concerning

methods of fishing and recording data are given in the sections concerning the various species.

Largemouth Black Bass

Largemouth black bass were caught by bait-casting with a plug, by trolling or still-fishing with minnows, or by fly fishing. Roughly, about 30 per cent of the fishing time was consumed in bait casting, 45 per cent in trolling or still fishing with minnows, and 25 per cent in fly fishing. Almost all of the bait casting and fly fishing was done on or near the water's surface and among or near beds of aquatic vegetation. In fishing with minnows the bait was 6 to 15 feet below the surface in water containing little or no aquatic vegetation.

Table 1 and Figure 1 contain data on the length-frequency distribution of largemouth black bass for each year from 1934 to 1938. The bass have been grouped by 1-inch intervals of length.

Table 1.—Summary of data on largemouth black bass from Whitmore Lake

Total length in inches	Length distribution for calendar year					Total number
	1934	1935	1936	1937	1938	
4.0— 4.9	....	....	....	....	23	23
5.0— 5.9	....	....	....	....	37	37
6.0— 6.9	....	....	....	....	31	31
7.0— 7.9	1	1	....	4	8	14
8.0— 8.9	9	13	....	2	4	28
9.0— 9.9	15	49	13	3	5	85
10.0—10.9[1]	33	57	56	2	9	157
11.0—11.9	12	32	19	13	12	88
12.0—12.9	10	25	16	11	8	70
13.0—13.9	7	3	13	14	11	48
14.0—14.9	3	6	5	4	5	23
15.0—15.9	....	5	7	....	3	15
16.0—16.9	1	1	3	2	2	9
17.0—17.9	....	1	2	1	1	5
18.0—18.9	....	2	1	1	1	5
19.0—19.9	....	1	....	....	1	2
20.0—20.9	....	....	....	....	....	....
21.0—21.9	1	....	....	....	....	1
Total number	92	196	135	57	161	641
Number per hour	0.7	1.4	0.5	0.3	0.3	....
Average length	11.0	11.5	11.8	12.3	12.2	....

[1]Minimum legal length for largemouth black bass.

1934.—Twenty-five of the 92 specimens, or 27.2 per cent, were under legal limit (10 inches); the remaining 67 specimens, or 72.8 per cent, were legal fish. They were caught at the rate of 0.7 per hour. The number of hours spent in fishing was 124.0. The average length was 11 inches. The single peak in the curve indicates that one to possibly three consecutive year classes formed the dominant group. Scale samples showed that, of the fish under 13 inches in length, all except a few were hatched in 1931 or 1932.

A study of about 20 nests, and observations of young disclosed that there apparently was a good hatch of fry, but that fall survival was low. About 10 per cent of the food of bass over 8 inches in length consisted of bass fry or fingerlings.

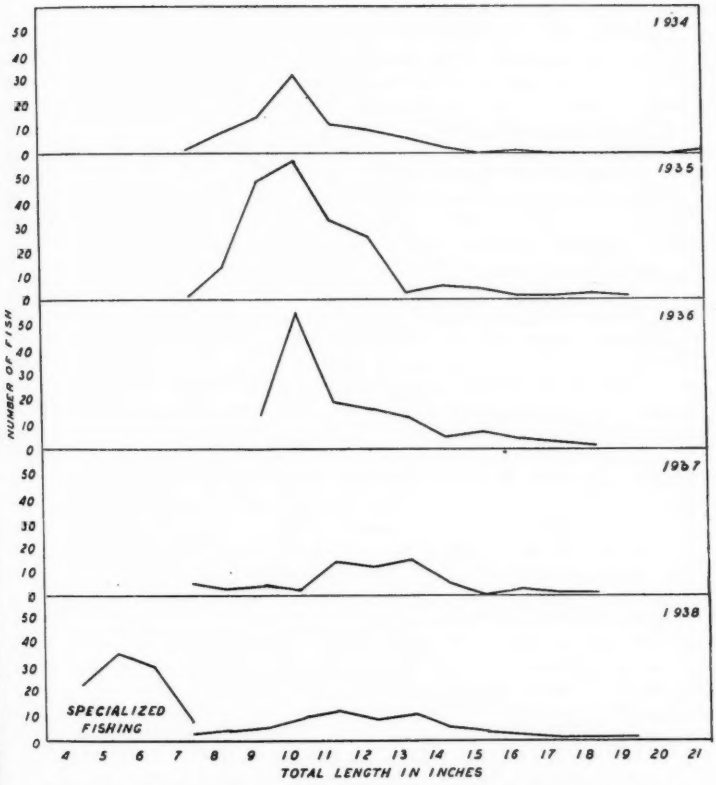

Figure 1.—Length-frequency curves for largemouth black bass for the years 1934-1938.

1935.—My records, and those of other fishermen, indicate that 1935 was the year of greatest cropping, and theoretically it was the year with the greatest population of catchable bass. Sixty-three of the 196 fish, or 32.1 per cent, were under the legal limit; the remaining 133, or 67.9 per cent, were legal fish. The average length of the specimens taken was 11.5 inches and the rate at which they were caught increased to 1.4 per hour. The number of hours spent in fishing was 140.5. Scale samples from 120 specimens showed that the year classes of 1931 to 1933 were dominant. About 30 nests were noted, and observations disclosed that the apparently good hatch of fry had almost

disappeared by mid-August. About 10 per cent of the food of bass over 8 inches in length consisted of bass fry or small fingerlings.

1936.—Only 13, or 9.6 per cent, of the 135 fish were under the legal length; the remaining 122, or 90.4 per cent, were legal fish. The average length of the specimens taken was 11.8 inches, and the rate at which fish were caught decreased to 0.5 per hour. The number of hours spent in fishing was 248.5. The year classes of 1931 to 1933 remained dominant. In 1936 fishermen began to complain about the poor bass fishing, and there was considerable agitation for increased stocking of hatchery fish. Many fishermen decided that Whitmore Lake was "going down" in bass fishing, and began fishing elsewhere. About 20 nests were observed and there appeared to be the usual number of fry hatched; however, the fry, instead of disappearing gradually, as they had done in 1934 and 1935, remained conspicuous. On quiet evenings of late August and early September many bass between 2 and 4 inches in length could be seen swimming in the shallow water and rising for insects. Again about 10 per cent of the food of bass over 8 inches in length consisted of bass fry or small fingerlings. The legal bass were noticeably fatter than were the fish of 1935, and this condition was commented upon by some fishermen.

1937.—Nine, or 15.8 per cent, of the 57 bass taken this year were under legal limit; the remaining 48, or 84.2 per cent, were legal fish. The average length of the specimens taken increased to 12.3 inches, but the rate at which fish were caught further decreased to 0.3 per hour. The number of hours spent in fishing was 188.0. The year classes of 1931 to 1933 were dominant. Fishermen complained bitterly about the bass fishing, and many demanded that the Michigan Department of Conservation "do something." In this year the water level was raised at least 3 feet. Many fishermen felt that the inflow of supposedly "clear water" would result in better bass fishing. Instead, bass fishing was poor, and furthermore, the water was less clear than in previous years. Those who liked to swim objected to the dirtier water and only speedboat owners seemed content.

Observations were made on about 15 nests. On quiet evenings of late August and early September vast numbers of young of the year, together with the preceding year's hatch, could be seen swimming in the shallow water or rising for insects. Some of the largest young formed groups of thousands and fed on insects, or brook silversides (*Labidesthes sicculus sicculus*) in the weedless waters, a habit never observed in previous years. The larger bass were often noted feeding among the groups of smaller ones, and apparently the larger bass were feeding on the smaller fish. Bass fishing was very poor in August. The legal bass were extremely fat.

1938.—By employing the same fishing methods as used in the previous years, 64 bass were taken, of which 11, or 17.2 per cent, were under legal limit, and 53, or 82.8 per cent, were legal fish. These fish were taken at the rate of 0.3 per hour; the number of hours spent

in fishing for them was 232.5; and the average length was 12.2 inches. In 1935, I frequently met as many as 40 fishermen a day fishing exclusively for bass; in 1938 I encountered 40 individuals only on the opening day of the fishing season. On many August evenings no bass fishermen were encountered.

About 20 bass nests were examined. By late August few fry of the year could be seen, but fingerlings between 3 and 8 inches in length were unbelievably numerous. On quiet evenings, and sometimes earlier in the day, these fingerlings formed huge schools near the water's surface. The size of the schools ranged from a fraction of an acre to several acres in extent, and occasionally as many as eight schools could be seen at once. The young bass often pursued the large schools of brook silversides or bluegill fry, frequently forcing these smaller fish to jump into the air. When the broad side of an oar was smacked upon the water's surface, thereby producing a loud noise, many thousands of young bass and their prey leaped into the air. Casting among these bass with a small spinner and fly almost invariably resulted in a strike. The 97 fish taken in 8.5 hours of this specialized fishing averaged 5.7 inches in length. I suspect that the average length of the bass in the school was not so great, and that only the longer, larger fingerlings could be hooked. Occasionally bass over 10 inches in length could be seen feeding among the schools of fingerlings, and several times large bass were observed pursuing or catching fingerlings. The legal bass were very fat. The water level of the lake remained high and almost stationary throughout the year.

Anglers' Opinions as to Conditions between 1924 and 1934

Many inquiries were made of fishermen as to conditions prior to 1934. Three men claimed that from "about 1924 to 1927" they took a few, very large bass, and that in "1928 and 1929" few large bass were caught, although many small ones were taken. Large bass again were caught in fair numbers in 1932 and 1933. The late Mr. Arthur Judson of Ann Arbor, told me that in 1932 he caught 19 bass, 12 of which were over 3 pounds in weight. In 1933 he caught large bass, but quit fishing in August because of the infrequency of strikes. In the spring of 1934, before I began fishing at Whitmore Lake, Mr. Judson predicted that I would catch very few fish, and that they would be very large. Fishing the areas he pointed out, with the same type of tackle as used by him, I got only one bass over 3 pounds, and the average length of all bass taken was about 11 inches. His efforts in 1934 resulted in catching small bass only, much to his surprise.

Bluegills

Bluegills were caught by fly fishing or by still fishing with worms, crickets, or grasshoppers as bait. Over 80 per cent of the fishing was with a fly and on or near the water's surface. The remainder was by still fishing at a depth of 3 to 40 feet. Over 90 per cent of the fishing was done between 6:30 and 9:00 p.m.

Table 2 and Figure 2 give the length-frequency data for each year from 1934 to 1938. The bluegills have been grouped by inches.

Table 2.—Summary of data on bluegills from Whitmore Lake

Total length in inches	Length distribution for calendar year					Total number
	1934	1935	1936	1937	1938	
4.0—4.9	148	7	....	....	37	192
5.0—5.9	96	102	398	305	417	1,318
[1]6.0—6.9	29	47	437	539	552	1,604
7.0—7.9	87	5	69	482	426	1,069
8.0—8.9	....	1	....	3	58	62
Total number	360	162	904	1,329	1,490	4,245
Number per hour	5.2	4.4	9.5	10.9	12.8	.....
Average length	4.0	5.8	6.1	6.6	6.5	.....

[1]Minimum legal length for bluegills.

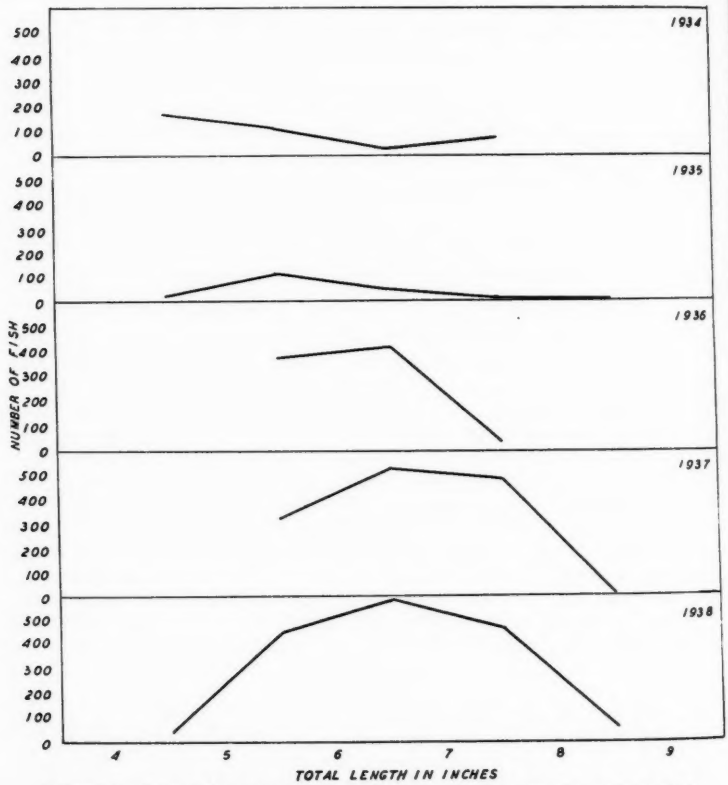

Figure 2.—Length-frequency curves for bluegills for the years 1934-1938.

1934.—Two hundred forty-four of the 360 bluegills, or 67.8 per cent, were under legal length (6 inches); the remaining 116, or 32.2 per cent, were legal fish. They were caught at the rate of 5.2 per hour. The number of hours spent in fishing was 68.5. The average length was 4.04 inches. The curve indicates two model length groups, one between 4 and 6 inches, the other between 7 and 8 inches. Scale readings disclosed that all except a few individuals in the smaller length group were hatched in 1931 and 1932, and those in the larger group in 1926 to 1928. On quiet evenings great portions of the water's surface were dimpled with small bluegills rising after insects, and occasionally the entire surface of the lake seemed to contain rising fish. In shallow water these small fish stole bait from the hook with exceeding rapidity, but because of their small mouths relatively few were taken. Occasionally a group of legal fish could be found feeding at the surface and fish of this size were caught much more easily. The majority of the bluegills between 7 and 8 inches in length were taken in deep water with bait. Apparently the smaller fish seldom penetrated more than 20 feet below the water's surface, and if the fisherman was successful in getting his bait down to that depth before the smaller bluegills ate it he had a chance of catching a larger fish.

Observations made on more than 500 nests indicated that there was a good hatch of fry. Soon after rising from the nests the fry swam into the dense beds of aquatic vegetation, but even there they were pursued and captured by larger fishes. By late August relatively few of the young of the year could be found, although bluegills between 3 and 5 inches in length were extremely numerous. Over 50 per cent of the stomachs of legal bass caught this year contained young bluegills.

1935.—One hundred nine of the 162 bluegills, or 67.3 per cent, were under the legal size limit; the remaining 53, or 32.7 per cent, were legal fish. Bluegills were taken at the decreased rate of 4.4 per hour. The average length increased to 5.8 inches. The decrease in the number of fish taken per hour was probably caused by the almost total absence of the more readily caught, larger fish. The increase in average length, despite the almost total absence of the 7- to 8-inch fish, was the result of increased growth in the smaller, dominant group. Only 36.5 hours were spent in fishing because the great preponderance of illegal fish in the catch made fishing undesirable. As in 1934, large portions of the water's surface on quiet evenings were dimpled with rising bluegills, and frequently the surface of the entire lake was seemingly disturbed by rising fish. It was very apparent that the lake contained a vast horde of bluegills between 3 and 7 inches in total length.

A study was made of hundreds of nests, and on July 14 slightly over 1,400 occupied or discarded nests were noted. Observations indicated a good hatch. By late August few young of the year were seen.

About 50 per cent of the stomachs of the legal bass caught this year contained young bluegills.

1936.—Three hundred ninety-eight of the 904 bluegills, or 44.0 per cent, were under legal length; the remaining 506, or 56.0 per cent, were legal fish. Bluegills were taken at the increased rate of 9.5 fish per hour. The number of hours spent in fishing was 95.0. The average length increased to 6.1 inches. The increased catch of fish per hour was undoubtedly the result of greater ease in capturing these larger fish. The increase in the relative abundance of legal fish from 32.7 per cent in previous years to 56.0 per cent made 1936 fishing more pleasurable; consequently a greater number of hours was spent in fishing. In this year fish between 3 and 4.5 inches in length were very few. On quiet evenings great numbers of bluegills between 5 and 7 inches in length could be seen rising to the water's surface, and on a few evenings the entire surface seemed agitated by the rising fish. Fishing for bluegills with bait in deep water was less productive than in any other year.

Several hundred nests were examined, and observations showed a good hatch of fry. By late August, many young of the year were observed at dusk about the weed beds or near the water's surface. The stomachs of about 50 per cent of the legal bass caught this year contained bluegills.

1937.—Only 305, or 22.9 per cent, of the 1,329 bluegills were under the legal size limit; the remaining 1,024, or 77.1 per cent, were legal fish. They were taken at the increased rate of 10.9 fish per hour, and their average length was 6.6 inches. Because of the large percentage of legal fish and the pleasure in capturing them, the number of fishing hours increased to 121.5. Again, fish between 4 and 5 inches in length seemed almost entirely absent. Large groups of legal bluegills could be seen rising in various portions of the lake on quiet evenings, but at no time did the entire surface of the lake seem to be disturbed as in previous years. In this year the submerged vegetation largely disappeared and the schools of bluegills seemingly concentrated about the emergent vegetation. Fishing in deep water with bait gave better results than in 1936. Scale samples from fish between 5 and 8 inches in length indicated that the vast majority had hatched in 1931 to 1933.

Observations were made on several hundred nests and the usual hatch of fry was noted. Contrary to other years, these young did not disappear by late August; instead they became more conspicuous. In early September thousands of bluegill young of the year were seen daily, despite depredations by the increasing numbers of bass fingerlings. A reason for the prominence of young bluegills may have been the comparative absence of submerged aquatic vegetation in which to hide. About 50 per cent of the stomachs of the legal bass caught this year contained small bluegills.

1938.—Four hundred fifty-four, or 30.5 per cent, of the 1,490 blue-

gills were below legal length; the remaining 1,036, or 69.5 per cent, were legal fish. The bluegills were taken at the surprising rate of 12.8 fish per hour. The number of hours spent in fishing was 116.0. The average length of the fish was 6.5 inches. In this year large numbers of bluegills under 5 inches in length were seen rising to the water's surface. Some of these small bluegills were caught, which fact caused a reduction in the average length for this year. Because of their larger size, and gregarious habits when feeding at the surface, the 6- to 9-inch bluegills were taken readily. However, they were more restricted in feeding and the schools were smaller than ever before. No longer could one see legal bluegills rising in all directions. Fishing in deep water with bait produced good results.

Some 500 nests were examined and the usual hatch of fry was noted. These young of the year were preyed upon heavily by the huge numbers of fingerling bass. By late August few small bluegills could be found despite a comparative lack of aquatic vegetation in which they could hide. The stomachs of about 50 per cent of the legal bass caught this year contained small bluegills.

Anglers' Opinions as to Conditions between 1924 and 1934

Inquiries of fishermen as to conditions prior to 1934 indicated that bluegill fishing varied considerably from year to year. The years, 1930 to 1933, were conceded to have been excellent for their fine catches of large fish. The scarcity of large fish in 1934 and 1935 was blamed on the continued lowering of the water level and failure to introduce adequate "new stocks" of bluegills. The small size of the 1934 bluegills was blamed on the lack of fish food, which in turn was held to be the result of the "stale" water and low water level in the lake.

Bullheads

Two species, the brown and yellow bullheads, occurred in the catches in almost equal numbers and were of the same average lengths during each year. Because of similarity in numbers and lengths, data on the two species have been combined for the preparation of Table 3 and Figure 3, and the two species are considered together in the following discussion. Unlike the largemouth black bass and bluegills, bullheads were seldom fished for by anglers at Whitmore Lake. Michigan residents avoided bullheads as though these fish were poisonous, and the little fishing for them was done by anglers from Ohio, Indiana, and other states to the south. Because of the small amount of fishing, cropping by man should not have been the factor it was with the largemouth black bass and bluegills. The bullheads were taken by still fishing on the bottom with worms and raw meat, in water between 5 and 30 feet in depth, and during late evening or night. Over 90 per cent of the fishing time was between 8:00 and 10:00 p.m.

Table 3.—Summary of data on bullheads from Whitmore Lake

Total length in inches	Length distribution for calendar year					Total number
	1934	1935	1936	1937	1938	
6.0— 6.9	8	1	1	2	....	12
7.0— 7.9	22	11	8	15	....	56
[1]8.0— 8.9	22	9	121	85	8	245
9.0— 9.9	45	....	157	132	56	390
10.0—10.9	11	...	71	77	103	262
11.0—11.9	21	....	....	....	58	79
12.0—12.9	1	....	....	....	1	2
13.0—13.9	....	....	....	....	1	1
Total number	130	21	358	311	227	1,047
Number per hour	2.2	2.0	2.2	3.7	1.8	.....
Average length	9.2	7.9	9.3	9.4	10.5	.....

[1]Minimum desirable length for bullheads.

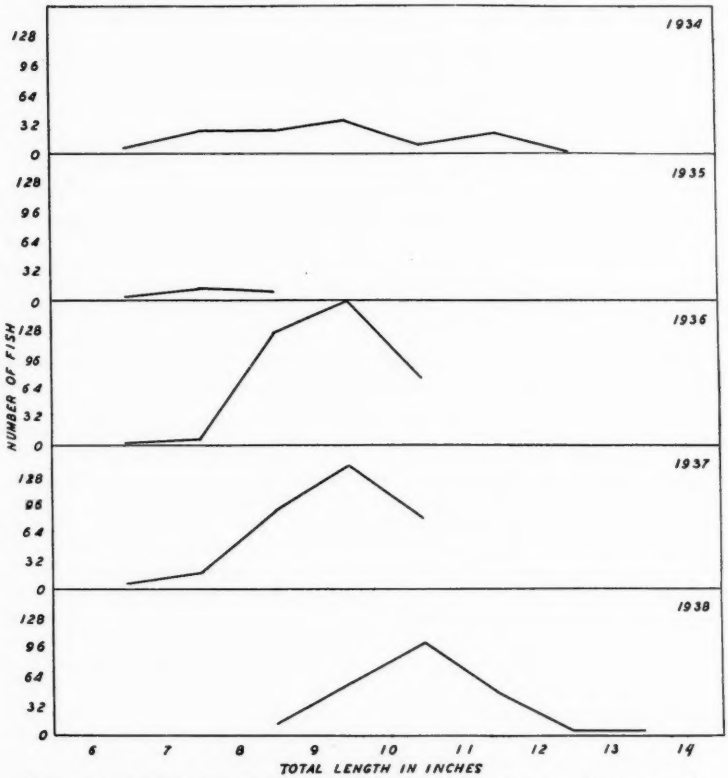

Figure 3.—Length-frequency curves for two species of bullheads (combined) for the years 1934-1938.

Table 3 and Figure 3 give the length-frequency curves for each year from 1934 to 1938. The fish were grouped by inches. Since there was no legal length for bullheads, 8 inches was chosen as the dividing point between desirable and undesirable fish.

1934.—Thirty of the 130 bullheads, or 23.1 per cent were under 8 inches; the remaining 100, or 76.9 per cent, were over. They were caught at the rate of 2.2 per hour. The number of hours spent in fishing was 57.5. The average length of the fish was 9.2 inches. The curve gives a slight indication of the presence of two model length-groups.

From mid-June until July 20 there was a considerable mortality among bullheads that were between 10 and 14 inches in length. Mortality had ceased almost entirely by August 1. The fish were greatly emaciated. Many had just finished breeding, while others retained some eggs or sperm. Despite the rather efficient "cleaning up" of the dead bullheads by turtles[2] there were at times as many as 150 fish lying along 200 yards of beach, and obviously, thousands died during the 2 months. These deaths may have represented a spawning or post-spawning mortality of old fish, which might have been avoided by more intensive cropping by fishermen. A few schools of fry were noted. Despite the vigilance of the guarding parents, these schools were preyed upon by bass. Bullheads between 1 and 7 inches long were eaten by largemouth black bass, particularly by bass over 13 inches in length. About 10 per cent of the bass stomachs that were examined contained bullheads.

1935.—The data for this year are too incomplete to be significant. Fishing was so poor that only 10.5 hours were spent in this occupation, and no specimens over 9 inches in length were taken. Twelve of the 21 specimens, or 57.1 per cent, were under 8 inches; the remaining nine, or 42.9 per cent, were over 8 inches long. The fish were taken at the rate of 2.0 per hour. The average length of the fish was 7.9 inches. The late June and early July mortality was greater than in 1934, and it was not unusual to find 150 or more dead bullheads along 200 yards of beach. These fish were greatly emaciated and showed evidence of having recently been engaged in spawning. During the periods of greatest mortality, the scavenging turtles had difficulty in consuming the supply of food. The few schools of fry noted were preyed upon by bass, and about 10 per cent of the stomachs of bass examined contained bullheads that were 1 to 7 inches in length.

1936.—Fishing improved markedly and only 9, or 2.5 per cent, of the 358 bullheads were under 8 inches; the remaining 349, or 97.5 per cent, were over 8 inches long. Despite the large numbers of specimens taken, none was over 11 inches in length. The average length was 9.3 inches. Fish were taken at the rate of 2.2 per hour. The number of

[2]The species of turtles were chiefly the musk turtle (*Sternotherus odoratus*), map turtle (*Graptemys geographica*), painted turtle (*Chrysemys bellii marginata*), and an occasional snapping turtle (*Chelydra serpentina*).

hours spent in fishing was 139.5. In contrast to previous years, the June-July mortality of large bullheads was almost entirely absent, and less than 10 individuals were found along the beach at any time. Apparently this older group was almost gone. The schools of fry were encountered more frequently than in previous years, and for the first time were conspicuous until mid-August. Small bullheads appeared in less than 5 per cent of the stomachs of bass.

1937.—Fishing conditions were very similar to those of 1935. Seventeen, or 5.5 per cent, of the 311 bullheads were under 8 inches; the remaining 294, or 94.5 per cent, were over 8 inches long. No specimens over 11 inches long were taken. The average length was 9.4 inches. Fish were caught at the rate of 3.7 per hour. The number of hours spent in fishing was 82.0. A total of about 12 large bullheads was found dead along the beach during June and July. About 20 schools of fry were encountered and young bullheads were conspicuous until mid-August. The stomachs of only 3 legal bass, all over 13 inches in length, contained bullheads.

1938.—All of the 227 specimens taken were over 8 inches in length and for the first time since 1934, specimens over 11 inches in length were captured. The average size, 10.5 inches, was greater than in any other year. Fish were taken at the rate of 1.8 per hour. The number of hours spent in fishing was 121.0. There was a slight increase in the June-July mortality over 1937 and as many as 8 moderately-sized or large individuals were found along the 200 yards of beach at one time. The schools of fry were encountered rather frequently, but apparently they were broken up before mid-August. Upon two occasions I saw a school of bass under 8 inches in length furiously swimming among a school of bullheads that were about an inch long. From their actions I assume that the bass were capturing bullheads. The stomachs of 2 bass under 11 inches in length contained bullhead fry and a 19.5-inch bass contained a bullhead that was 4 inches long.

Probable Causes of Annual Fluctuations in the Size and Abundance of Fish

The rod-and-line catch of fish during the 5-year period at Whitmore Lake indicated an annual fluctuation in the average length of the four dominant species. Most of the catchable fish were apparently the result of successful survival of fry from the spawnings in the years 1931 to 1933. The average length of largemouth black bass increased annually from 11.0 inches in 1934 to 12.3 inches in 1937; the length of bluegills from 4.0 inches in 1934 to 6.6 inches in 1937; the length of bullheads (two species) from 9.2 inches in 1934 to 10.5 inches in 1938 (except in 1935 when insufficient data were obtained). The decrease in the average length of bass and bluegills in 1938 probably was caused by the addition of small fish from successful spawnings in 1936 and 1937. The survival of fishes spawned in 1934 and 1935 apparently was very low.

The evidence indicates that in 1934 there was a remnant population of large bluegills and bullheads that were hatched earlier than 1929. With the bass, there was little evidence of similar older age groups.

The year 1935 was the most favorable for catching bass, and presumably the largest number of catchable fish was present then. After 1935, fishing declined, probably because of intensive cropping in 1935 and the scarcity of fish of the 1934 and 1935 year classes.

Legal-sized specimens of the slow-growing bluegills, hatched in the years 1931 to 1933, did not figure prominently in the catch until 1936. The largest population of legal-sized bluegills appeared to be present in 1937, but more fish were taken per hour in 1938, because the larger average length of these small-mouthed, gregarious sunfishes enabled one to capture them more readily.

Bullhead fishing was poor in 1934 and 1935 but was improved in 1936 to 1938. The dominant group, presumably spawned in 1931 to 1933, could not be caught readily until 1936.

Bass, bluegills, and bullheads, hatched presumably in the same year, seemingly do not reach their peak of easiest capture at the same time; thus, bass attained this peak in 1935, bluegills in 1937 and 1938, and bullheads in 1936 and 1937. When the largest population of fish of catchable size was apparently present, the catch per hour of that species was the highest.

The evidence gathered during the period 1934-1938, agreed largely with the statements of fishermen concerning changes in average length and numbers of the various fish species in many Michigan lakes during certain years.

The reasons for the apparent cyclic fluctuation in the length and numbers of fishes during various years are not known. The explanation may lie in a predator-prey relationship, such as Dr. David H. Thompson found in the bottom-land lakes along the Illinois River (Clements and Shelford, 1939, p. 188). If so, then possibly for a few years a group of fish predators, such as the largemouth black bass, will be numerous enough that they can eat all except a few of the fry produced during those years. Later, this group of predators decreases in numbers because of cropping by man, natural mortality, or other factors, thereby permitting the survival of a large number of fry in one or in a number of consecutive years. These survivors belong to species in the predator and/or prey classes. As a possible example: The bass hatched in the years 1931 to 1933 were so numerous as to be able to devour most of the fry produced in 1934 and 1935. The year classes of 1931 to 1933 became so reduced in numbers by 1936 and 1937 as to be unable to consume most of the fry produced in those years. The young of 1936 and 1937 were so abundant in 1938 that unless a great reduction in numbers occurred they might devour most of the fry produced in the next few years, thus making possible another cycle.

Variations in average length and numbers may determine the success of spawning seasons. If so, it is interesting to note that the years

of greatest fry survival were apparently years when the supply of adult largemouth black bass appeared to be low.

Fluctuations in the supply of basic foods or small organisms that feed upon these foods, such as plankton, may contribute to the cyclic variations in the numbers and average lengths of fishes.

Unfortunately, the lake conditions were altered greatly by the rise in water level in 1937, which fact may have had effects on fry survival and on the ability to catch adults. It is significant, however, that the first year in which the fry apparently survived in large numbers came before the abrupt rise in water level.

It is possible that a combination of all of the factors mentioned above, plus many more, were responsible for the cyclic fluctuations.

Because of the differences in the sizes and numbers of the various fish species in different lakes during the same year, as indicated by the statements of fishermen, no universal factor, such as sun spots, appears to control the cyclic fluctuation; rather it appears, if the information of fishermen can be relied upon, that the cyclic fluctuation in each lake is independent of the cyclic changes in other lakes. No evidence exists to prove that the cyclic fluctuations in Whitmore Lake are always of the same period of time or of the same intensity.

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STUDIES ON THE LIFE HISTORY OF THE PUGET SOUND STEELHEAD TROUT (*SALMO GAIRDNERII*)[1]

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ABSTRACT

Steelhead trout are taken in great numbers as immature fish by stream anglers during the regular trout season. They also are caught during the winter months as they ascend the rivers to spawn. Posters were put up along the rivers describing the tagging experiments and requesting the anglers' cooperation in returning the tags of marked fish captured. No attempt was made to obtain a complete check on the trout fishermen, and 121 tags were returned voluntarily during the 1938 trout season. Cooperation of the trout fishermen was poor and many tagged fish were not reported.

During the 1940 winter fishing season, a daily check was made of the fishermen. Scale samples, temperatures, weights and lengths and other data were gathered. Through the anglers' cooperation, accurate information was received concerning nearly all catches not actually checked.

Scale samples taken from anglers' catches of immature fish indicated that the major portion of their catches consisted of fish 2 years of age. Comparative measurements between scale samples of immature fish (gathered in April) and scale sample of mature fish, indicated that the probable peak of the downstream migration occurred during May. The bulk of the spring steelhead trout catch, to all appearances, consisted of fish either in the process of migration, or nearly ready to migrate.

A study of the scale samples of mature fish indicated that 73 per cent of the fish had migrated to salt water as 2 year old fish. It was found further, that 61 per cent of the fish matured after 2 years in salt water, and 28 per cent matured after 3 years in salt water. In all, 52 per cent of the fish were found to have spent a combination of 2 years in fresh water and 2 years in salt water before maturing.

A comparison of the 1940 sport catch with the 1940 trap collections showed that 885 fish comprised the sport catch and 1,160 fish constituted the trap catch. Much natural spawning takes place in the main river. The sport fishery for mature steelhead trout appears to take only a small percentage of the total run.

A management plan for the Green River is suggested which would reduce the take of immature fish. The plan also provides for a 15-day extension of the winter fishing season. This extension of fishing season is to utilize a portion of the migration run which comes into the river after the regular season. It is felt that the Green River steelhead trout is a composite of several races, each having its specific time of migration and a portion of each run should be taken without injuring materially any particular run.

INTRODUCTION

The steelhead trout or sea-run rainbow trout (*Salmo gairdnerii*) is considered the chief game fish in western Washington. Not only is it taken in large numbers by the trout fishermen in the spring, but the number of anglers during the period from December to March is large

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and increasing steadily. The steelhead trout, a migratory fish, spends its life passing through a series of wide and varied natural and man-made conditions.

Throughout this paper, the terms "mature" and "immature" will be used to designate different periods in the life history of the steelhead trout. Immature applies to the young fish prior to their initial entrance into salt water; mature fish are those returning from salt water to fresh water for the purpose of spawning.

The necessity of obtaining accurate information relative to the life history of the steelhead trout manifested itself in 1936 when the State Game Department planted more than 16,000 1-year-old fish in Green River during the summer closed season. It was believed that the steelhead trout would migrate to salt water during the summer months, thus escaping the fishery for immature trout. When the season opened in the fall of 1936, the majority of the fish caught were the planted steelhead trout. They could be identified readily by the nipped dorsals which are prevalent among pond-reared steelhead. A series of tagging experiments on the Green River was conducted in order to obtain the pertinent facts necessary to properly administer this game-fish resource.

In making a study of this nature, the material must, of necessity, be collected over a comparatively long period of time. A portion of the data used in this paper has been gathered by the following men of the Biological Staff of the Washington Department of Game: Messrs. Harlan Cheyne, Don Earnest, John Johansen and Arthur Knutsen. Appreciation is expressed to Dr. J. L. Kask and Dr. L. R. Donaldson for their help and advice. Cooperation was also extended by the personnel of Seward Park Ponds and by King County game protectors. We wish to thank the winter steelhead fishermen who also gave whole-hearted support to the endeavor.

Physical Aspects of the Green River

The Green River is a typical coastal stream. It rises high in the Cascade Mountains, flows rapidly through forests and deep canyons for approximately three-quarters of its length or about 65 miles. The lower reaches flow slowly through the highly cultivated Auburn Valley and enter the tidewater at the southern limits of the City of Seattle. The region above the Headworks is closed by the City of Tacoma as a health measure to insure pure water for domestic use. The upstream migration is terminated at the Headworks Dam. From the dam down to the Flaming Geyser the vertical canyons and hard traveling exclude all but the more rugged fishermen. From the Flaming Geyser to its mouth the stream is paralleled by excellent highways. The lower reaches below Kent have undergone flood control work with its accompanying channel straightening, brushing, etc. In this region the bottom is muddy and sandy providing a poor habitat for aquatic

insects and unsuitable grounds for spawning. The stream has an average width of about 100 feet in this area.

Below the Headworks Dam three tributary streams enter the river. Newaukum Creek is closed to fishing and is used for spawn-taking as well as "nursery" purposes. There is a trap on Soos Creek, maintained by the Washington Department of Fisheries. Steelhead trout spawn is collected for the State Game Department in addition to salmon operations of the Department of Fisheries. A similar collecting trap is operated below the Headworks Dam. The only other major tributary below the Headworks is Mill Creek which flows through the Auburn Valley and is unsuited for spawning. In addition to the steelhead trout, the stream supports four species of salmon, a few cutthroat and Dolly Varden trout, numerous whitefish, cottoids, suckers, squawfish and some dace. Water temperatures range between 40° and 55° F. throughout most of the year.

Extent of the Fishery

The steelhead trout fishery on Green River is purely for sport; nevertheless it is large in scope. During the winter season of 2 months in 1940, a careful daily check revealed that approximately five thousand anglers fished the river. During the summer season, an even larger number of fishermen may be encountered. The evaluation of the catch is necessary in determining administrative policy. The main restrictions on the fishery other than the closed seasons have been as follows: (1) Regular fishing season, April to October, cutthroat and rainbow or young steelhead trout, 6 inches minimum size, daily limit of 20 fish, weekly limit of 40 fish. Newaukum Creek is closed to all fishing, and the main river is closed for approximately 2 miles below the Headworks Dam. (2) Special steelhead trout season, January and February, steelhead trout, 16 inches minimum size, daily limit of 3 fish with 6 allowed each week. The main river only has been opened during the special steelhead trout season and then only up to the Flaming Geyser bridge.

Problem

To obtain direct evidence as to migration time and the extent of fishery, 5,000 14-month-old steelhead trout were marked by means of an internal tag consisting of a small red celluloid strip, 3/16 by ¾ inches, lettered "Return to Wn. Game Dept." A slit was made in the body wall just posterior and dorsal to one of the ventral fins through which the tag was inserted entirely into the body cavity. In order to reduce the chance of injuring the intestine, the fish were starved at least 72 hours before marking. The adipose fin also was clipped as an external mark of identification. The fish were held in the rearing ponds for over 3 months after marking to determine tag losses and degree of mortality. The marking was begun on August 3 and the

fish were planted on November 13, 1937, after having been held for observation for 14 weeks and 5 days. The number of fish that lost tags was 96, or 1.9 per cent, and 82 fish, 1.6 per cent, died during the period of retention in rearing ponds.

All of the dead fish were preserved and examined later. In most of the dead fish, the tag appeared to lie in such a position as not to have been the cause of death. In some instances, the tag had moved from its original position and resulted in a constriction of the intestine near the vent. In other individuals, it had become embedded firmly in the tissue. Six of the 82 dead fish had lost their tags.

Planting

The fish were starved for 3 days prior to planting, and were carried in an 800-gallon tank truck equipped with twin circulating pumps. One load of about half the fish was liberated below the Headworks Dam, while the other half was liberated in Burns Creek, a side-flow of the main river. No mortality could be detected during or after the planting. All fish were planted on the same date, November 13, 1937. After deducting the number that lost tags and died during the holding period, 4,818 tagged fish were liberated.

Returns

Prior to the opening of the 1938 trout season, posters were nailed in conspicuous places along the river. These called the anglers' attention to the fact that there were tagged fish in the stream. The posters described the method of tagging, showed a picure of a young steelhead with the adipose fin encircled, and asked the anglers' cooperation in sending in the tags to the Game Department. Posters were also placed in sporting goods stores in communities near the river. Although the river was visited periodically by biologists for the purpose of obtaining scale samples and other data, no attempt was made to obtain a count of the daily catch on the stream. The large number of fishermen, coupled with the fact that entrance was possible anywhere along the 35 miles of open fishing water, made such a check impractical. The responsibility for turning in tags was impressed on the anglers at every opportunity. It was believed that sufficient returns could be obtained in this manner to give the desired information. A total of 121 tags was recovered from the catch of immature fish.

The return represented but a small part of the tagged fish taken. Many anglers admitted catching one or more tagged fish during the trout season, but "just hadn't gotten around to mailing in the tags." The first one or two tagged fish taken by local anglers were quite a novelty and the tags were mailed to the Game Department to satisfy the fishermen's curiosity. They were mailed a mimeographed letter giving the history of the fish and those letters were shown to other anglers. As soon as the curiosity concerning the tags was satisfied, there was little incentive for sending in additional tags. One individual

alone took 30 tagged fish during the 1938 spring season but the Game Department failed to receive a single record.

Tags returned from catch of immature steelhead trout during 1938 were as follows:

Dates	*Number of tags*
April 23-29	41
April 30-May 6	24
May 7-13	11
May 14-20	5
May 21-27	4
May 28-31	11
July 3	1
Unknown	17
Total	[2]114

The fish caught on July 3 was from a small area inadvertently left open to fishing. One of the total number of recoveries was obtained from droppings of a blue heron.

During the time the returns were obtained, there was a definite trend for the later returns to come more frequently from the lower part of the river. The number of returns fluctuated in accordance with the stream conditions and fishing intensity. Throughout the middle of May, heavy rains kept the river quite high, making fishing conditions unfavorable. The main river did not produce all of the tags, for early in the season several were recovered in Soos Creek and Burns Creek, but no tagged fish were taken in either of these places after the first week in May.

The evidence gathered pointed to the occurrence of downstream migration during the spring months. Since the fishing season opened late in April, information could not be obtained as to when the migration began or its extent prior to the opening. From the unpublished work of Royal and Ellis, 1938-1939, obtained incidental to their study of migratory tendencies of the Pacific salmon at the Minter Creek station, a total of 672 steelhead trout downstream migrants were counted through their trap between April 2 and June 11, 1939. Of the total, 449 or 71.6 per cent passed through the trap during the 3-week period May 1 to May 21, 1939. No downstream steelhead migrants were found between September 1, 1938, and April 2, 1939. This downstream migration of immature steelhead trout was referred to by Taft (1936), in explaining the Waddell Creek experiment. Additional weight is given to the evidence of the spring migration by the fact that no tag recoveries were received from a later release of another series planted in November, 1938, when the trout season opened June 1 instead of in April of the year 1939.

During the special fishing season for steelhead trout during January

[2]Seven additional tags were obtained prior to the opening of the legal fishing season.

and February, 1939, three tags were received from sportsmen representing small mature males 19 to 21 inches in length and weighing 2½ to 3 pounds. An additional, small marked male was reported from the Newaukum Creek trap in April.

During the 1940 winter steelhead trout fishing season, a daily check was made in order to get as complete data as possible regarding the catch of mature fish. All fish obtainable were weighed and measured, scale samples were collected, and temperatures and river fluctuations were recorded. Fishermen contacted were made acquainted with the work and their cooperation was solicited. From Kent downstream, the fishing was confined mostly to eddies and pools. The fishermen would arrive early and spend several hours or all day in one spot, making it easy to contact them. From Kent upstream, the fishermen would cover considerable distance as they would "drift-fish" the pools and riffles, which made it difficult to check them all each day.

Daily records were kept of all fishermen contacted. Estimates were made of the previous day's total catch and the total number of anglers. As most of the anglers visited the river regularly, they soon became acquainted with the work and were very cooperative. In the 2-month period, 2,317 anglers were interviewed who had caught 303 steelhead trout. It is estimated that a total of 5,000 anglers took 885 fish. During this period of time, 30 marked fish were either examined or their tags received from the anglers. Six additional marked fish entered the Newaukum trap, and one was taken at the Headworks trap.

Examination of 15 tagged fish disclosed that many of the anglers were overlooking both the marks on and the tags in the fish. During the 2½-year interval since tagging, mesenteries had overgrown some of the tags, so they could easily escape casual observation; also, some of the tags had moved into areas where they were completely concealed. One tag found by a housewife, was embedded in the muscular tissue of the back near the dorsal fin. A thorough search of the body cavity of the fish had previously failed to reveal this tag. In another fish, after noting the absence of the adipose fin, the tag was founded embedded in one of the testes. Still another tag was located between the air bladder and the kidney. It was found also that many of the fish had lost tags. Out of the thirty fish examined by biologists and anglers, 12 had lost tags. It is of interest to note that out of 15 fish first examined by a biologist, 11 were found to have retained their tags. Out of 15 fish first examined by sportsmen, 8 were reported as having lost their tags. This leads us to believe that probably several of the fish examined by anglers contained tags which were not found.

The following facts based on tag recoveries give information on the homing instinct of steelhead trout. Twenty-nine recoveries were made in the main river in which the fish were planted, and 6 recoveries were made in a tributary of the same river, although no fish had been

planted in the tributary. One fish was captured in the north fork of the Klatskanine River in Oregon, which is a tributary of the Columbia. This fish went out through the Straits of Juan de Fuca and down the coast to the mouth of the river and migrated upstream, a total distance of bewteen 300 and 400 miles. Another fish was taken in the Skagit River, which empties into the Sound about 75 miles north of the Green River. A third fish was reported taken in the Snoqualmie River which empties into Puget Sound about 35 miles north of the mouth of Green River, but since this fish was not seen by a member of the Game Department and the angler could not find the tag, it was not included in the data. The two strays examined which had been taken outside out of the parent river system represent a stray loss of 5.4 per cent and lead to the belief that such a loss may be much larger than is usually presumed. The total of 162 tags received represents a return of 3.3 per cent which is small. Had the cooperation from the trout fishermen been better, this figure would have been much larger. As will be shown later, some of the steelhead trout do not mature until after 3 years in salt water, so additional returns are expected during the 1941 winter season. The take of 30 marked fish from the Green River by the 1940 winter fishermen represents 9.9 per cent of the individual catches examined, and 3.4 per cent of the estimated catch.

A considerable variation in growth was found in the marked fish. At one extreme, two fish were found which weighed between 4 and 5 pounds, and the two largest weighed between 10 and 11 pounds. The average weight of the marked fish was 6¾ pounds as compared with an average of 7¼ pounds for 117 wild fish.

The marked fish at the Newaukum trap were measured, re-marked and liberated, so no data can be shown regarding their loss or retention of tags. The tagged fish taken at the Headworks trap was killed and examined and the tag was found where it had been inserted originally into the body cavity.

Information on Age and Growth

From a management standpoint, it is quite essential that data be obtained concerning the age of the species as it enters the catch. Scale samples were gathered from immature steelhead trout caught during April, 1936. In April, 1937, additional scale samples were obtained from immature fish caught in the lower half mile of Soos Creek, below the hatchery. This area annually is fished by several hundred on the opening day alone. The Green River scale samples from mature fish were gathered at points selected at random along the river during January and February, 1940.

Table 1 shows the percentages of various year groups caught. The immature fish were taken in the brackish water of lower Green River. In the Soos Creek sample there was a decided increase in the percentage of 1-year-old fish in the catch, with a corresponding decrease

in the older groups. The Green River mature group shows an interesting correlation of groupings of fresh-water checks when compared with the data obtained from the scales of immature fish from Green

Table 1.—Distribution of anglers' catches of steelhead trout according to number of fresh-water winter annuli exhibited by the scales

Item	Number of winter annuli	Number of fish	Percentage of total number
Immature, Green River	1	14	18.9
	2	55	74.3
	3	4	5.4
	4	1	1.4
	1-4	74	100.0
Immature, Soos Creek	1	12	30.8
	2	25	64.1
	3	2	5.1
	1-3	39	100.0
Mature, Green River[1]	1	16	16.0
	2	73	73.0
	3	10	10.0
	4	1	1.0
	1-4	100	100.0

[1]Classified on basis of fresh-water winter annuli laid down prior to downstream migration.

River, except in the 3-year-old group where the percentage was nearly doubled. While data gathered from hook and line fishing may be considered selective, nevertheless we believe these to be quite representative of the total sport catch.

As the immature fish were taken in April, it is quite probable that they reach the peak of their migration shortly after this time, probably in May. We therefore concluded that the bulk of the sportsmen's

Table 2.—Length-frequency distribution according to standard length in centimeters and age groups (representing number of winter annuli) of immature fish in anglers' catches

Age group	Length interval[1] (centimeters)	Number of individuals
I	13.5-14.5	5
	14.5-15.5	9
	15.5-16.5	11
	16.5-17.5	1
	Total	26
II	12.5-13.5	3
	13.5-14.5	4
	14.5-15.5	20
	15.5-16.5	13
	16.5-17.5	16
	17.5-18.5	14
	18.5-19.5	6
	19.5-20.5	0
	20.5-21.5	2
	21.5-22.5	2
	Total	80
III	17.5-19.5	1
	19.5-21.5	1
	21.5-23.5	0
	23.5-25.5	3
	25.5-27.5	1
	Total	6
IV	25.0	1

[1]Mean lengths: age-group I, 15.2 centimeters (6.0 inches); age-group II, 16.6 centimeters (6.5 inches); age-group III, 22.7 centimeters (8.9 inches).

catch during April and May consists of fish approaching, or actually making, their downstream migration. The lengths of the fish taken at different ages are presented in Table 2. On casual inspection it appears that the fish made little growth between the first and second years. This is not true, however, since the 6-inch minimum size limit caused only the fastest growing fish which were able to reach a length of 6 inches the first year, to enter the sample in the one-winter group. Many undersized fish are caught and thrown back, and an average sample of the entire year group would greatly reduce the mean size shown in Table 2.

A large portion of the fish spent 2 years in fresh water and 2 years

Table 3.—Age of steelhead trout at the time of reaching sexual maturity. Data based on examination of scales of 100 fish

Number of annuli (winters of life)		Number of fish and percentage
Fresh-water	Ocean	
1	2	10
1	3	6
2	0	2
2	1	4
2	2	52
2	3	17
3	1	3
3	2	4
3	3	2
Total		100

in salt water. Actually this held true for 52 per cent of the fish. Table 3 shows the actual variations in age found *before* reaching sexual maturity. The reason for the large number of variations and different year combinations as shown in this table is unknown.

Artificial Propagation

Egg-collection records for 1939 and 1940 are submitted in Table 4. The number of fish trapped during 1939 and 1940 compares quite closely and the smaller total egg collection during 1940 was due to the larger number of fish being released above the racks without being

Table 4.—Record of steelhead trout captured for artificial propagation during 1939 and 1940[1]

Trap location	Year	Females		Males		Number of eggs collected
		Trapped	Spawned	Trapped	Spawned	
Headworks	1939	100	100	123	123	362,000
	1940	108	96	111	90	350,800
Soos Creek	1939	123	123	130	130	429,451
	1940	75	75	86	86	190,912
Newaukum Creek	1939	293	232	293	201	703,450
	1940	416	197	364	131	407,800
All	1939	516	455	546	454	1,494,901
	1940	599	368	561	307	949,512

[1]A grand total of 1,062 fish was trapped in 1939, and 1,160 in 1940. Fish not spawned artificially were released upstream from the traps.

spawned. It is interesting to compare the total number of fish trapped in 1940 (1,160 fish) with the estimated anglers' take of 885 fish. These figures show that the winter fishermen in 1940 took only 43.3 per cent of the *known* run. Emphasis should be placed on the fact that many fish do not enter the traps, but spawn in the main river, as repeated observations have shown in the areas accessible for such observations. From a management standpoint, it is apparent that under conditions such as existed in 1940, the winter fishery cannot be accused of depleting the species.

While making the daily examination of the river during the 1940 winter season, observations were made relative to the effect of flow and temperature on the migratory tendencies. The greatest stimulus for upstream migration appeared to be an increase in the amount and rate of flow of water, for continuous rains, with the accompanying rise both in flow and temperature, would cause an increase in the number of fish caught. Anglers who fished tidewater consistently made their best catches during periods when high tides were recorded. The entire lower river produced the best "still fishing" when the river was high and off-color.

No information can be offered regarding the speed at which the fish move upstream. Sea lice, parasitic marine copepods, were generally absent from fish caught more than 10 or 12 miles above the upper tidewater limit. However, one fish was observed nearly 20 miles above tidewater which had still retained several of these organisms. It was also noted that the fish were in varying degrees of ripeness when caught, even in tidewater. The majority of the female fish taken in the lower river could be classified green, but this condition seemed to change rapidly as evidenced by fish caught further upstream.

Many of the fish were badly scarred from encounters with enemies, giving rise to considerable speculation regarding the natural mortality of the immature populations during their sojourn in salt water. Torn and missing maxillary bones on many fish indicated that they had been hooked but escaped from the anglers prior to or during the downstream migration.

Application of Data

Each different stream system presents a distinct problem. General application of known facts may be made for similar systems, but first it is necessary to know local conditions and proper evaluation is the first step in formulating a management policy. If the greatest value to the fishery lies in the capture of immature fish, every possible means should be used to increase that take by regulating more stringently on the fishery for mature steelhead trout. If the greatest value lies in the fishery for mature individuals, the yield should be increased by proper protection of the immature fish. In general, steelhead trout streams which are too small to provide angling for large fish, and streams that are not well adapted for spawning and rearing purposes,

should be devoted to small trout fishing exclusively. Those streams of sufficient size to allow long casts and plenty of room to play the large fish should be devoted to the taking of mature fish. Adequate closed seasons and areas are necessary for the escapement of small fish. Sufficient spawning escapement must also be provided through limitating the length of seasons and maximum catches, and the provision for closed areas.

Natural mortality is difficult to evaluate accurately since the steelhead trout spends about one-half of its life in the ocean where adequate data cannot be obtained. In order that natural mortality may be determined accurately, it is suggested that marking experiments be conducted on streams closed to all kinds of fishing. Both upstream and downstream traps should be operated to enable counts and recoveries to be secured. To determine the efficiency of artificial stocking, both hatchery fish and wild fish should be marked.

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Discussion

Dr. Huntsman: May I ask Mr. Pautzke whether he has any valid information as to whether these different runs of fish were specific races or populations, and if so, how does he designate them?

Mr. Pautzke: We have checked on runs on these rivers through spawning operations over a period of 10 years. At the time of the spawning operations the runs of fish come in at specific times. As to the intensity of fishing, during the last 5 years the river has been open to angling during January and February, and before that commercial fishing was permitted in the river. So far as the actual run is concerned, there is an early run, a slacking off, then a later run in March. In the early run the fish are small, averaging 8 or 9 pounds. The later run is composed of fish as large as 16 or 18 pounds.

Dr. Huntsman: Have you any proof that a specific race of an early period produced offspring that came back at an early period?

Mr. Pautzke: No. I take it your question is whether early fish produce early fish. I cannot answer that.

Dr. Huntsman: The word "race" is used, apparently, as having a certain significance—population or race; but there is no hereditary implication. In that case of course you would be quite correct.

Mr. Gordon: Some years ago there was a decided conflict of interest between the sport fishermen and the commercial fishermen on some of the runs of fish in the West. Is it true that the conflict and constant bickering that existed some years back, has been overcome?

Mr. Pautzke: Yes, it was originated by the sportsmen. There is no more commercial fishing for steelhead trout except in the Columbia River, and I look forward to the time when the commercial capture of steelhead trout will be discontinued. The sportsmen are well-organized.

Mr. Gordon: Do steelhead trout enter into the commercial fisheries in Puget Sound?

MR. PAUTZKE: No. After the young leave fresh water they disappear, and that is one of the reasons for lack of information concerning the interval between the time the fish migrate and become ready to spawn.

DR. GREELEY: What was the longest period that elapsed between the time of tagging of a particular fish and its recapture?

MR. PAUTZKE: Three years. Fish returned this past spring that were tagged in 1937. In the course of this work some interesting conditions were noted in connection with the method of internal tagging. For instance, I found that different results followed different methods of making the incision. The first incisions were across the muscle fibres, and the action of the tail tended to keep the wound open. We cooked a fish and skinned it to study its muscle structure. We found that the muscles that operate the ventral fins lay in a diagonal position; therefore we changed our procedure and made the incisions parallel with the muscle fibres, and this muscle tension closed the wound. The loss of tags decreased. Then we found that we were penetrating the intestine, so we starved the fish for 72 hours prior to making the incision. This deflated the intestine and immediately the mortality went down. Since we kept every fish that died, we were able to determine the reason for the mortality.

DR. GREELEY: That is very interesting, because in 1933 when I was working in Michigan we tried an experiment with rainbow trout. I would not care to give any quantitative data because only a small lot of fish was involved, but with the internal tags we did not lose a single fish. A few months afterwards the hatchery superintendent began to pick up tags in the pond; they had worked through the body cavity and had been shed by the fish. It appeared to be due to magic; the wound healed up and yet the fish were without any tags.

MR. PAUTZKE: We clipped the adipose as a mark of identification for the game protectors when examining the fishermen's catches. We found that if the celluloid tags were placed in a container with sand and shaken around so that sharp edges were removed the tendency for the tags to work out of the body was reduced.

We tried anchor tags, but we found that in a short time an open sore developed and the tags worked out. We also tried strap tags, but because of the rapid growth of the fish the tags tended to be sloughed or tended to break off. Operculor tags were sloughed off too.

DR. GREELEY: These experiments with internal tags are interesting. In connection with the work that was being carried on in Michigan another experiment was run in a brook trout hatchery. There was furunculosis in the hatchery—I won't mention the name of the hatchery; the superintendent would not appreciate it. At any rate, every time we cut into one of the brook trout they died, yet in the small lot of rainbows we did not kill a fish. One obtains greatly varying results in tagging experiments; it is necessary to run many of them and to use all the known methods.

THE EASTERN BROOK TROUT IN THE MALIGNE RIVER SYSTEM, JASPER NATIONAL PARK

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ABSTRACT

The eastern brook trout was first planted in the Maligne River System in 1928. The success of the introduction was phenomenal and these waters, previously barren of fish, were opened to angling in 1932. From 1933 to 1937 the population suffered a severe decline in size and condition. During the past 3 years the fish have recovered their condition and their average size is increasing steadily. Three problems of fish culture and management have arisen in the development of angling in this area. The choice of the brook trout, an "exotic" species, appears to have been justified. The lack of intervention when the fish began to degenerate has also been vindicated by the natural recovery of the population. A new problem in management has appeared in the sudden and unexplained decrease in the number of fish caught during the past 2 years.

INTRODUCTION

The Maligne River System of Jasper Park, including Maligne, Medicine and Beaver Lakes, drains through a deep canyon into the Athabaska River. It was barren of fish until the eastern brook trout, *Salvelinus fontinalis*, was planted in 1928. The immediate success of this introduction and the fine angling which followed the opening of these waters in 1932, are known to anglers and fish-culturists both in Canada and the United States. During the years 1933 to 1937 the quality of the fish deteriorated rapidly but in the past 3 years there has been a marked improvement. It is now of interest to analyze the catch records and to correlate them with the biological data available for the area.

The information needed for this study has been accumulating in various places over a period of 20 years. During this time the Maligne area was inspected by at least four officers of the Department of Fisheries, investigated briefly by six biologists and fished by a number of expert anglers. Most of these authorities have left some record of their findings in reports, scientific papers and popular articles. The record of the anglers' catches kept by the National Parks Bureau since 1933 has been a most important source of information. The author made two trips to the Maligne area during the summer of 1939 and a more extended visit in 1940.

This paper is essentially an account of fish culture and management in the area together with the physical and biological data necessary for general understanding. More detailed accounts of the fauna of the region have been published in other journals. The author feels

that there is a great need for materials which will help to bridge the gap between biological surveys and fish-cultural practice. Such accounts will be of much use to fishery managers in other regions. They should also help the biologist to criticize and modify his surveys in the light of actual fish-cultural needs.

The author is indebted to the National Parks Bureau for generous cooperation in this study.

Location and Surroundings

The extent and disposition of waters in the Maligne area is indicated in the accompanying map, Figure 1. Maligne Lake is by far the largest in the region, and probably the largest in the Canadian Rockies. Its drainage area is not large (possibly 200 square miles) but it is fed by several large glaciers. The lake is at an altitude of 5,460 feet and is surrounded by magnificent peaks, a number of which rise to more than 10,000 feet. Five or six streams flow continuously into the lake

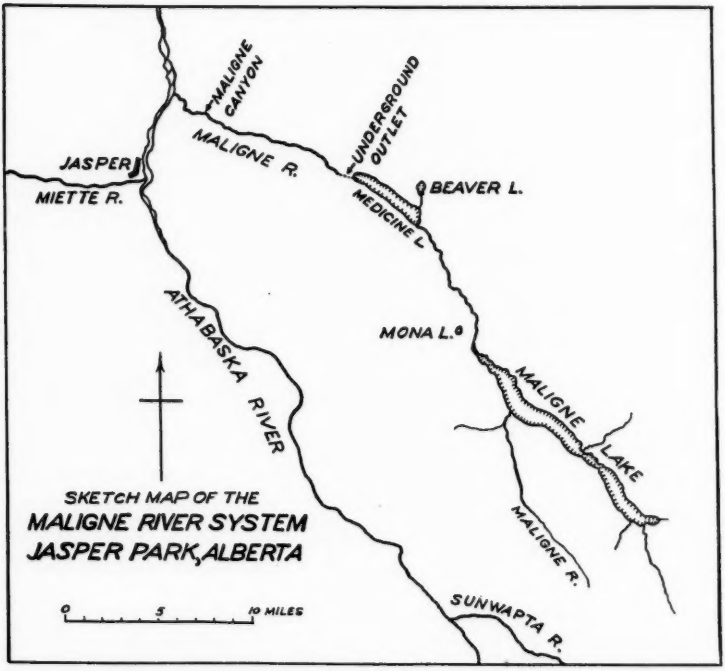

Figure 1.—Sketch map of the Maligne area, Jasper National Park

and several of these have lower gravelly stretches which provide good spawning grounds for trout. The Maligne River is large and very swift, dropping from 5,460 feet at Maligne to 4,700 feet at Medicine Lake, a distance of about 11 miles.

The basin of Medicine Lake has been formed by a morainic mass which cuts across the valley. Unfortunately this moraine does not hold water and after the peak of the summer flow the lake level declines rapidly. In August the lake may have less than half its maximum area and in the autumn it is only a narrow channel.

Two small lakes, Beaver near the upper end of Medicine, and Mona near the lower end of Maligne, have been important trout producers. Beaver Lake, with an area of only 90 acres, has produced about two-fifths of the fish from the whole area.

The Maligne River, emerging from the underground outlet below Medicine Lake, continues as a swift stream, dropping about 1,400 feet in approximately 14 miles to join the Athabaska. As it emerges into the valley of the Athabaska it goes through a deep canyon which provides a complete barrier to the fish of the lower valley.

Physical and Chemical Conditions in Maligne Lake

Maligne Lake is a narrow body of water 14 miles long and 8.37 square miles in area. The shoreline is fairly irregular and shelves off rapidly into great depths. The maximum depth observed in 110 soundings was 315 feet, 2½ miles from the upper (southeast) end of the lake. In the lower part of the lake (between the outlet and the narrows) the greatest depth is 250 feet and the mean depth for the whole lake is 132 feet.

The water of the lake is always cold. The ice usually breaks up during the last 2 weeks of May and forms between November 15 and December 30. Series of temperature observations from surface to bottom have been taken at various times between July 7 and August 31. During this period the temperatures have been as follows:

Surface	10.5 to 13.3° C. (51 to 56 ° F.)
10 meters (33 feet)	7.5 to 8.3° C. (45.5 to 47 ° F.)
40 meters (130 feet)	4.3 to 4.6° C. (39.7 to 40.3° F.)
90 meters (295 feet, bottom)	4.1° C. (39.4° F.)

It is evident that the lake never gets very warm. The highest mean temperature for the whole lake was 6.2° C. (43° F.) on August 11, 1940. The temperature from 40 meters to the bottom varies less than 1° F. throughout the season and the bottom temperature is almost constant at 39.4° F.

The dissolved oxygen and hydrogen-ion concentration were examined with each series of temperatures. As in all large alpine lakes, the oxygen content was high. At the surface it varied from 4.8 to 5.9 cubic centimeters per liter, saturation values of 80 to 94 per cent, and at the bottom 5.6 to 6.5 cubic centimeters per liter, representing

saturation values of 75 to 86 per cent. It is clear that there is never any shortage of oxygen in such a lake. Determinations of hydrogen ion concentration show that the water is slightly alkaline, with pH values of 7.8 and 7.9 at the surface and 7.6 to 7.7 at the bottom.

The lake is heavily silted throughout the summer since it is fed directly from several large glaciers. The silt is noticeably denser toward the upper (southeast) end, where most of the glacial streams enter the lake. Secchi's disc readings varied from 0.5 meters near the upper end to 2.0 meters near the outlet. The visibility of this white disc to depths of only 1.5 to 6.5 feet indicates the limited extent to which light penetrates the lake water. Further evidence of the heavy silting is found in the bottom deposit which in the deep water is composed of a heavy grey silt almost lacking in organic matter.

Flora and Fauna of Maligne Lake

The plankton of the lake was studied by Bajkov (1929) who reported 42 species of microscopic plants and animals. The writer took samples during the summers of 1939 and 1940 chiefly for quantitative purposes although several additional species have been found. The dominant forms in the writer's collections are the copepods *Cyclops viridis* and *Diaptomus tenuicaudatus,* the cladoceran *Daphnia pulex,* the protozoan *Ceratium hirundinella* and two diatoms, *Asterionella formosa* and *Stephanodiscus niagarae.* Several rotifers and algae were common but not present in large quantities.

The methods of measuring the quantity of plankton in a lake are so varied that the expression of results in any absolute unit is likely to be misleading. It is useful, however, to compare the amounts collected in different lakes using the same methods. Thus the plankton from total vertical hauls in Maligne Lake, 90 meters deep, is about equal to similar hauls from Beaver Lake only 1.5 meters deep. Beaver Lake is a small, clear body of water in the Maligne valley. Similar hauls from Lake Annette, a small lake near the place where the Maligne River enters the Athabaska, yield about four times as much plankton as Maligne Lake. Two other lakes in the Canadian Rockies which have dimensions similar to those of Maligne produce more plankton but these lakes are not silted. It may be said, therefore, that the plankton of Maligne Lake is not heavy but of reasonable quantity in view of the heavy silting.

The bottom fauna has been sampled with 46 dredgings representing the various parts and depths of the lake. The numerical composition of the bottom population may be expressed as chironomid larvae 60 per cent, Sphaeriidae 20 per cent, oligochaete worms 19 per cent and miscellaneous organisms 1 per cent. In the shallow water close to shore there are large numbers of caddis, mayfly and stonefly larvae. also amphipods, snails and leeches. The aquatic insects have been reported in an earlier paper by Neave (1929), the leeches by Bere (1929) and the molluscs by Mozley (1930).

The average number of macroscopic bottom animals over all depths is about 550 per square meter (460 per square yard). This compares favorably with the numbers found in smaller lakes at lower altitudes in the Jasper region. It is also similar to the numbers found in clear lakes of the same size as Maligne in other parts of the Canadian Rockies. It seems probable, therefore, that the bottom animals are not affected adversely by the heavy silting to the same extent as is the plankton.

The rooted aquatic vegetation of the lake is composed chiefly of *Potamogeton, Ceratophyllum* and *Chara.* These are most evident in the shallow region at the Narrows and in the outlet bay. Most of the shoreline is too exposed and the bottom too shelving to support much rooted vegetation. This is in marked contrast to the condition in Beaver Lake where almost the entire bottom is covered by beds of *Chara* and other rooted plants.

In its biological as well as in its physical characteristics Maligne Lake is typically alpine and highly oligotrophic, i.e., deep, cold, well-oxygenated and with a rather sparse flora and fauna.

Introduction and Progress of Trout in Maligne Lake

The introduction of eastern brook trout, *Salvelinus fontinalis,* was begun in July, 1928, by the planting of 190,000 fry. Most of these (178,000) were placed in Maligne Lake, the remainder in the creek between Beaver Lake and Medicine Lake. In 1929 a second planting of 208,000 fry was made and in 1931 a final planting of 179,000. The eggs from which these fry were hatched were obtained from the Paradise Brook Trout Company at Stroudsburg, Pennsylvania.

The fish grew rapidly and on September 25, 1929, 16 months after planting, some specimens were recorded from 14 to 18 inches in length and with a maximum weight of from 1½ to 2 pounds. Many of these fish were ready to spawn. In September, 1931, some fish 4 pounds in weight were taken from Maligne Lake, and in December of the same year one of 6 pounds was captured. At the same time fish weighing more than 4 pounds were reported from Beaver Lake and some of 6 pounds from Mona Lake. A growth to 6 pounds in 3½ years was considered remarkable, especially in a glacial lake such as Maligne.

The lake was opened for fishing on June 1, 1932, and many anglers obtained with ease their limit of 15 fish from Maligne and Beaver Lakes. Some of these fish weighed over 5 pounds. Unfortunately, there is no official record of the fish caught during 1932 but the catches were very heavy and there was soon a general demand for a reduction of the catch limits.

In 1933 a compulsory registration of catch was adopted and this has been continued up to the present year. The catch statistics are summarized in Tables 1 and 2 and in the graphs, Figures 2 and 3. The annual catches from the whole area are shown in Table 1, along with

Table 1.—Catch statistics for the Maligne System, 1933 to 1940

Year	Total weight (pounds)	Total number	Average weight (ounces)	Number of permits	Number of fish per permit	Pounds of fish per permit
1933	7,421	4,809	24.0	595	8.1	12.5
1934	8,544	7,316	19.0	950	7.7	9.0
1935	8,798	8,378	17.0	952	8.8	9.2
1936	5,339	7,003	12.2	974	7.2	5.5
1937	5,596	8,779	10.2	1,127	7.8	5.0
1938	5,731	8,248	11.1	1,140	7.2	5.0
1939	4,365	5,387	13.0	946	5.7	4.6
1940	1,175	1,040	18.1	466	2.2	2.5

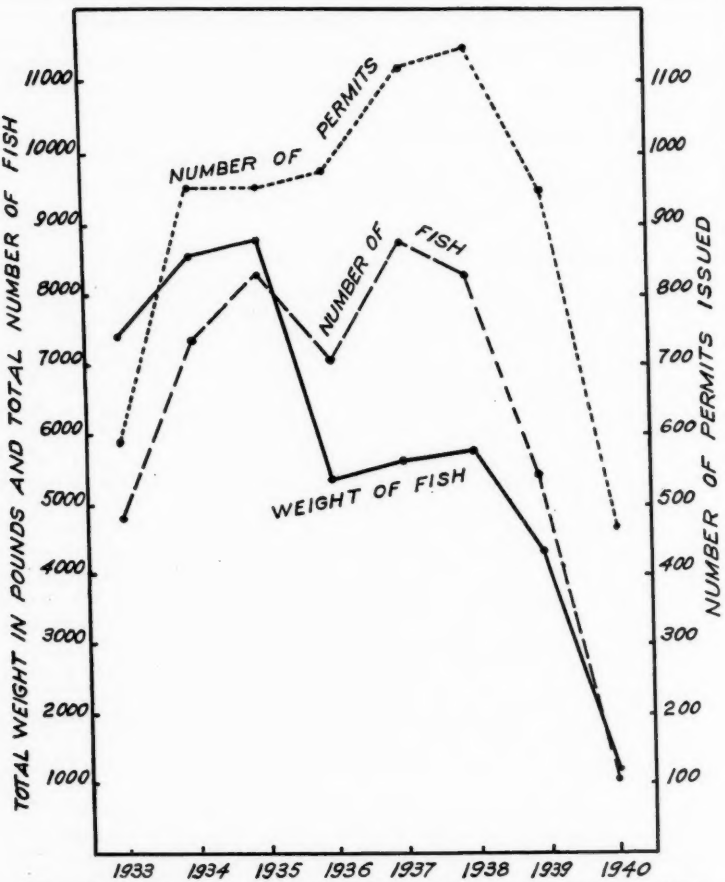

Figure 2.—Fluctuations in the total catch and permits issued in the Maligne System, 1933-1940

Table 2.—Fish catches from the separate waters of the Maligne System, 1933 to 1940

Year	Maligne Lake		Medicine Lake		Beaver Lake		Maligne River	
	Total number	Average weight (ounces)	Total number	Average weight (ounces)	Total number	Average weight (ounces)	Total number	Average weight (ounces)
1933	1,951	23.2	.....	.....	.....	.....	.....	.....
1934	2,173	23.5	.....	.....	.....	.....	.....	.....
1935	1,492	24.8	2,036	22.6	4,388	11.5	291	18.0
1936	946	18.8	1,773	15.7	2,829	7.4	1,194	13.8
1937	872	18.4	2,474	12.4	3,928	6.1	1,435	12.3
1938	418	17.3	2,478	14.2	4,005	7.5	1,266	14.2
1939	850	19.2	1,578	13.7	2,444	10.3	515	13.0
1940	218	18.0	130	16.8	402	18.9	291	17.4

the number of permits issued. The latter provides some indication of the fishing effort. The fluctuations in the annual catch are readily followed in Figure 2. It will be seen that in 1933, 1934 and 1935 the catch increased both in numbers and in total weight. In 1936 there was a decided slump in the numbers caught and a more pronounced drop in the total weight. Since the number of permits issued had increased slightly this must represent a real deterioration in the fishing. In 1937 the total number of fish increased up to the level of the 1935 catch but the total weight increased very little. In 1939 and 1940 the numbers and total weight diminished rapidly until the catch is now less than one-quarter of that taken in the early years. The total number of permits issued has also dropped to about one-half the former level.

The average weight of fish from the different waters is indicated in Table 2 and Figure 3. From an average for the whole system of 24 ounces in 1933 it decreased to 10.2 in 1937 and has since increased to 18.7 in the past season. The separate waters all show this decrease to a greater or lesser degree. In Maligne Lake the decrease did not begin until 1937 and the average size never dropped below 17 ounces. In Beaver Lake the average dropped to 6.1 ounces at the low point in 1937, but it has since made rapid recovery.

We are unable to explain why, through the whole period of degeneration, the number of permits issued held up and even increased (see Fig. 2). It is also difficult to understand why, during the period 1938-1940, when the fish were in good condition and their average size was increasing rapidly, the number of permits and the total catch fell off so violently. Were the fish decreasing so rapidly in numbers, becoming harder to catch, or were the fishermen less skillful? Our net sampling in Maligne Lake does not suggest that the fish were less numerous in 1940 than in 1939. In Beaver Lake the number taken in a test net in 1940 was 20 per cent less than in 1939 but the total weight of the catch had increased 100 per cent. A partial explanation may be found in the observation that the large fish are much harder to catch than the smaller ones. In previous years the inexperienced angler often caught his limit in Beaver Lake. In 1940 he caught very few and

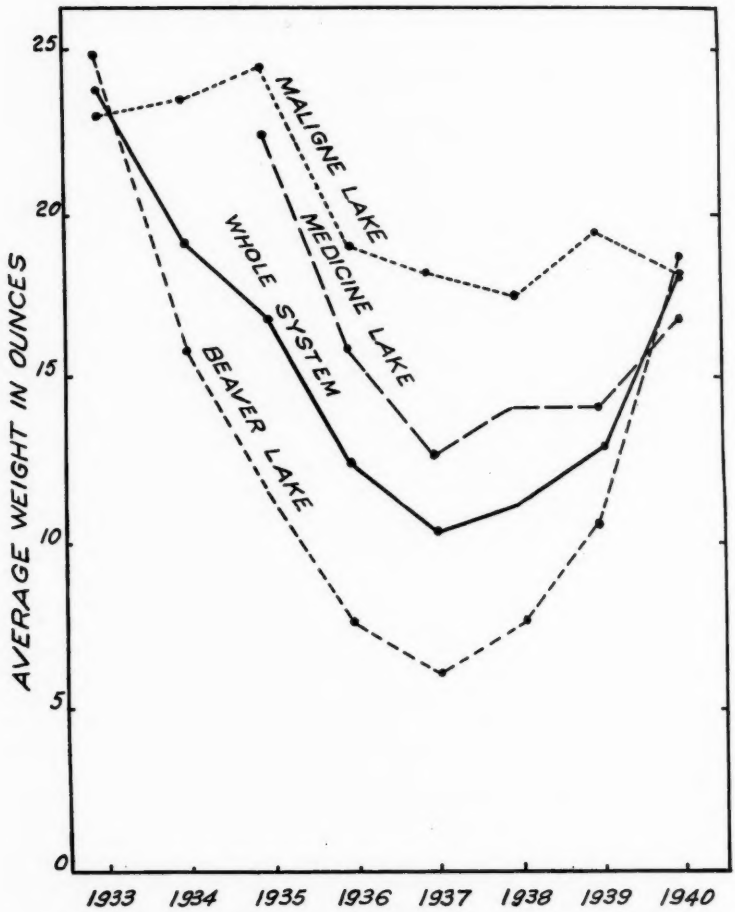

Figure 3.—Average weight of the trout caught in the various waters of the Maligne System, 1933-1940

even the expert angler rarely caught more than three fish in as many hours. The decrease of 50 per cent in the number permits issued may be in part a reflection of this difficulty. The ease with which large fish were caught in the first years after stocking is quite understandable in view of the abnormally great number of large fish present. As

evidence of this condition we may quote from a report of Bajkov and Neave (1931) in which they stated that in September, 1929, when they "set a thirty-foot gill net near the outlet of Maligne Lake, over 400 fish were caugh in about two hours."

A history of extremely rapid initial growth, then degeneration in size and condition and later a gradual recovery, is often found when lakes formerly "barren" have been stocked with fish. The reasons for this cycle of events are not understood. The commonly mentioned explanation of "too many fish for the food supply" is not supported by the evidence available for Maligne Lake. It seems more probable that, with a large number of fry planted in 1929, these fish grew at approximately the same rate and thus prevented the cannibalism which is probably an important factor in keeping the balance of age groups in a normal population. Presumably the abnormally numerous early generations are now largely dead and the lake is supporting a normal but much smaller number of large fish. Thus the difficulty should not be ascribed simply to "too many fish" but rather to the presence of too many *large* fish. Also, since there is no evidence that the food supply was depleted we may suggest that the only shortage was that of food organisms suitable for large fish.

This suggestion is not presented as a complete or final explanation of the cycle. It is obvious that this important phenomenon is in need of much further study, especially in locations such as the Maligne System which are favourable for the collection of catch statistics. Until we understand the factors causing this degeneration we can hardly expect to devise a system of management which will cure or prevent it.

The Present Fish Population of the Lake

The present brook trout population of Maligne Lake has been investigated by the examination of about 200 trout taken mostly in gill nets during 1939 and 1940. In both years the net used was a gang composed of 25-yard lengths of 1½-, 2-, 3-, 4-, and 5-inch stretched mesh. On July 8, 1939, this net was set near shore about one-third of a mile from the outlet and left over night. It caught 47 fish varying from 12.5 to 35.0 centimeters[1] (5¼ to 15 inches) in length and weighing 1 to 27 ounces. On August 31 the catch in the same place was 41 fish varying from 13.5 to 31.0 centimeters (6 to 14 inches), 1½ to 20 ounces. The largest fish examined was a female 43 centimeters (18¾ inches) 2½ pounds, caught at the outlet of the lake. In 1940 a setting on August 10, in the same place as those of 1939, caught 36 fish ranging from 13.2 to 34.0 centimeters (5½ to 15 inches), 1 to 24 ounces. Six other gill net settings were made at various depths and in different parts of the lake. The catches indicated that the fish were more or less uniformly distributed around the whole shoreline

[1]Lengths of fish recorded here in centimeters are standard lengths, the distance from the snout to the end of the caudal peduncle. Those recorded in inches are lengths to the fork of the tail.

but mostly in shallow water. There were no fish caught at depths greater than 9.5 meters (31 feet) and only four per cent of the catch was from depths below 6 meters (20 feet). The zone in which these depths are found represents only 12 per cent of the lake and the fish feed almost entirely in this restricted area.

The food of the brook trout in July, 1939, was mostly chironomid larvae and pupae. The diet of eight fish taken by angling near shore

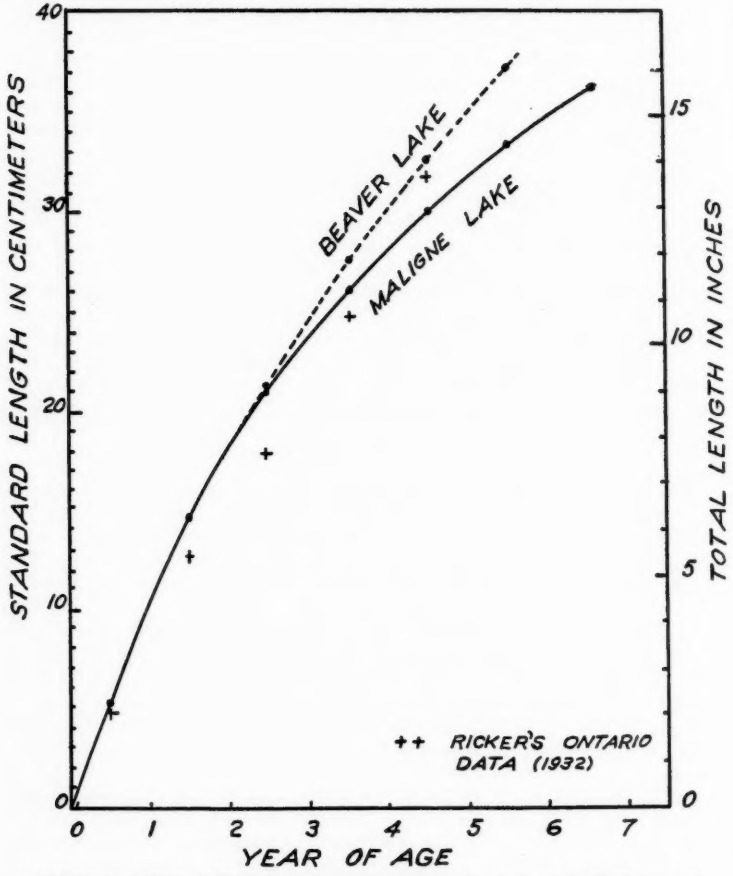

Figure 4.—Rates of growth in length of eastern brook trout in Maligne and Beaver Lakes

was composed of chironomid larvae to the extent of 85 per cent, and the remainder of stonefly, mayfly and caddis larvae. Fourteen fish taken in nets at the same time had eaten 40 per cent amphipods, 30 per cent chironomids, 15 per cent caddis larvae, and some other insect larvae and terrestrial beetles. On August 31 a group of 25 brook trout of selected sizes, caught in the gill net, had eaten the following: Caddis larvae, 45 per cent; amphipods, 40 per cent; some snails and aquatic insects. A total of 78 stomachs was examined between August 10 and August 18, 1940. The fish were taken in seven different localities and selected to represent all sizes. The chief foods taken during this period were *Daphnia,* 35 per cent; caddis larvae and pupae, 30 per cent; and mayflies, 17 per cent. The remainder of the stomach contents was made up of chironomid larvae and pupae, amphipods, gastropods and some terrestrial insects. We may conclude that the main foods of the brook trout in Maligne Lake are caddis, chironomid and mayfly larvae, amphipods and *Daphnia.* It is also evident that their diet varies considerably throughout the season.

The rate of growth of trout in Maligne and Beaver Lakes has been determined by the examination of scales from 70 specimens taken in 1939 and 1940. Ten of these individuals were rejected later when the scale markings could not be interpreted satisfactorily. The growth curves therefore are based on the average rate of growth of about 30 individuals from each lake. The first four age groups could be observed as distinct modes in the length distribution of seine and gill-net catches. These modes were found to correspond with the average size of each age group as determined by scale readings. The rates of growth for trout from both lakes appear in Figure 4. In Maligne Lake the average length and weight of brook trout of the different age groups on August 1, 1940, is indicated in the upper part of Table 3. The average lengths and weights of fish of the different age groups in Beaver Lake appear in the lower portion of the same table.

Table 3.—Average lengths and weights of eastern brook trout according to age group, from Maligne Lake and Beaver Lake

Age group	Standard length (centimeters)	Fork length (inches)	Weight (ounces)
MALIGNE LAKE			
I	6.0	2.5	.....
II	14.5	6.2	1.2
III	21.0	9.0	6.0
IV	26.0	11.2	10.5
V	30.0	13.0	16.2
VI	33.5	14.5	23.0
VII	36.0	15.5	27.5
BEAVER LAKE			
I	6.0	2.5	.....
II	15.0	6.5	1.6
III	21.5	9.2	6.1
IV	27.5	11.7	12.5
V	33.0	14.2	25.0
VI	37.0	16.0	39.0

The rate of growth for the first 3 years is similar in both lakes but in the fourth to sixth years the growth in Maligne is considerably slower. The more rapid growth in Beaver Lake no doubt is explained by the fact that it is shallow, warm and rich in trout food, especially *Gammarus*. It is probable that Maligne Lake has less food of a kind suitable for the larger fish. In both lakes the rate of growth is much slower than in the years immediately following the introduction when, as reported above, some fish grew to 18 inches and 2 pounds in 16 months and to 6 pounds in 3½ years. The present rate of growth in Beaver Lake is slightly faster than that recorded by Ricker (1932) in Ontario lakes and streams.

The size at which the brook trout in these lakes become sexually mature varies rather widely. In most of the specimens examined it appears to be between 22 and 30 centimeters. Thus most of the fish would spawn after completing 3 or 4 years of life.

Problems of Fish Culture and Management in Maligne Lake

During the development of angling in this watershed the National Parks Bureau was confronted with two difficult problems. The first was the choice of species to be introduced and the second the treatment to be applied when the population degenerated in 1935 and 1936. We may now review these problems in the light of later developments.

The decision to plant the eastern brook trout was reached with some difficulty and only after various authorities had urged several other species. The introduction was made after this species was recommended by a biological survey party which examined the lake in 1925 and 1926. The decision now appears to have been thoroughly justified. The eastern brook trout has provided good fishing and the population has become self supporting. The lakes have produced large numbers of fish of good size and quality. They have been caught successfully on the fly, with spinners, trolls and bait, thus providing attractive fishing for anglers of all sorts.

The most common objection to the introduction of this species was that it was an "exotic." This criticism was made prior to the introduction and revived during the period of degeneration. While the indiscriminate use of exotic species is to be deplored, the criticism does not seem to carry much weight in this instance. The watershed is sharply cut off from adjacent areas and there are very few lakes to which the fish might gain access if they escaped into the Athabaska River. The latter river already contains another and less desirable species of *Salvelinus*, the Dolly Varden charr.

At least four other "trout" had been urged as suitable for introduction into the area. The lake trout, *Cristivomer namaycush*, was suggested since the lake was large and deep like those commonly inhabited by this species. While the lake trout would no doubt have lived in the lake it would have necessitated the further introduction of a for-

age fish such as the Rocky Mountain whitefish, *Prosopium williamsoni*, or the cisco, *Leucichthys artedi*. The introduction of a forage fish would be a hazardous step and in any case the lake trout is definitely inferior as a game fish.

The brown trout, *Salmo trutta*, was also asked for but these cold waters are obviously unsuited to this species. It has been planted in small lakes, with no outlet, near the town of Jasper and has failed to provide desirable angling.

The cutthroat trout, *Salmo clarkii*, and rainbow trout, *Salmo gairdnerii*, cannot be dismissed so readily as possible choices for the area. We may point out, however, that the cutthroat trout was introduced into the heavily silted Mistaya Lakes in the Banff Park with only mediocre results. These lakes, like Maligne, were formerly barren of fish. The rainbow trout is apparently native in the upper Athabasca-Miette drainage and might be urged for that reason. It might have provided better fly fishing than the eastern brook trout but it would not provide the variety of fishing which has made the Maligne System attractive. In any case, the rainbow trout has been planted in Amethyst and Brazeau Lakes in the Jasper Park. These are lakes of considerable size, heavily silted and situated at high altitudes. Amethyst Lake has been teeming with trout for several years but the fishing has not been considered superior to that in Maligne.

The suggestion has been made that another species might not have suffered the severe degeneration which occurred in the eastern brook trout population of Maligne Lake. The exact cause of this degeneration is not known but similar occurrences have been observed among both the cutthroat and rainbow trout in "barren" lakes of the Canadian Rockies.

The general question of whether spring or fall spawning species should be planted in these high silted lakes cannot be answered as yet. We may note, however, that the mature rainbow trout in Amthyst Lake are spawning until late in July and they are therefore in poor condition through a large part of the fishing season. The eastern brook trout, being fall spawners, are in excellent condition in Maligne Lake all through the fishing season. There are many other lakes at high altitudes in the Rockies where the delayed spring spawning of the rainbow trout interferes with the angling.

The second major problem in the management of the Maligne area was the severe degeneration of the fish population in the years 1935 and 1936. The situation appeared to be critical and various "cures" were advocated. Looking back, it seems fortunate that no treatment was attempted and that the population was allowed to make a natural recovery.

The procedures which were recommended included introducing a forage fish, introducing a predacious trout and encouraging heavier fishing of the population by angling or netting. The forage fish suggested for introduction included the smelt, *Osmerus mordax*, the Ko-

kanee (land-locked Pacific salmon), *Oncorhynchus kennerlyi*, the Rocky Mountain whitefish, *Prosopium williamsoni*, and *Couesius plumbeus*, a large and common minnow of the upper Athabasca drainage. It is possible that a forage fish might make it possible to take from Maligne Lake a larger quantity of eastern brook trout. However, the lake has been producing a reasonable quantity of fine game fish. It is our opinion that the risks involved in experimenting with the introduction of a forage fish are too great to justify such a step at the present time.

The lake trout was suggested as a large predacious form which if introduced would feed on the eastern brook trout and keep the numbers of the latter species under control. The lake trout has been criticized above as an undesirable in this lake. There can be no question of whether the angler prefers eastern brook trout fishing to deep trolling for lake trout. In any case the eastern brook trout population has adjusted itself without the help of any predacious species.

Heavier fishing might possibly have hurried the process of recovery which has been going on during the past 4 years. Netting was not attempted and it was difficult to encourage more angling when the fish were in such an unattractive condition.

It was suggested above that the recovery was accomplished without any interference and that this may have been the desirable procedure. If, as we suspect, the degeneration resulted from the absence of cannibalism among the first year classes it would seem possible to avoid this occurrence by a reduction of the number planted during the years required for the initial stock to grow to maturity and to spawn. It should thus be possible to build up a population in which the relative numbers of the different age groups were similar to those in a natural population of long standing. The suggestion is offered as worth testing when other barren lakes are to be stocked.

A third problem has now arisen through the sudden drop in the catches during 1939 and 1940. This question is now being studied by a fishery manager, recently appointed by the National Parks Bureau to supervise the fisheries of Jasper Park.

Summary and Conclusions

1. Maligne Lake is a large, deep, cold and heavily silted alpine lake in the Canadian Rockies near Jasper.

2. The lake formerly was barren of fish but possessed moderate quantities of plankton and bottom organisms which would provide food for fish.

3. After a biological examination in 1925 and 1926 it was recommended that eastern brook trout be planted in the watershed.

4. The introduction was begun in July, 1928, and continued in 1929 and 1931. The fish grew rapidly, spawned in about 18 months and some weighed 6 pounds in 3½ years. The lake was opened to fishing in 1932 and excellent catches were made.

5. About 5 years after the introduction, the larger fish deteriorated rapidly and in 1935 to 1937 they were in very poor condition.

6. From 1937 to 1940 the fish regained their condition and the average size of the fish caught still is increasing.

7. In spite of this improvement there has been a marked decrease in the catches of 1939 and 1940. This cannot be explained at present.

8. The trout are now growing more slowly than those originally planted but the population is maintaining itself by natural reproduction and appears to be in a healthy condition.

9. The trout feed almost entirely in the shallow water (less than 20 feet deep) near shore. The chief foods taken are the larvae of caddis, chironomids and mayflies, also amphipods and *Daphnia*.

10. It is concluded that the introduction of the eastern brook trout was quite justified although the species is an "exotic." It has provided attractive angling and has not interfered with the species indigenous to the region.

11. When the fish population began to degenerate various treatments, including the introduction of forage fish, were recommended. No action was taken and the population appears to have made a natural recovery.

12. It is pointed out that the collection of complete data as to the fish caught is essential for fishery management. Such information is needed to deal with the present problems of the area, namely, the recent drop in the annual catch and the cyclic fluctuation in the average size of fish caught.

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THE EFFECT OF A BEAVER DAM ON THE INSECT FAUNA OF A TROUT STREAM[1]

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ABSTRACT

A qualitative and quantitative investigation of the distribution of aquatic insects in Mud Creek, Algonquin Park, Ontario, has been carried out during the summer months of the last 3 years. Samples of the population present were obtained by trapping the insects which emerged from 1 square yard of water surface.

In the first season the field station described in this report was characterized by a rubble bottom and rapid flow of water. These conditions remained unaltered during the first part of the second season and the insect emergence for this period corresponded closely with that of the previous year. In early July, however, beavers constructed a dam across the stream flooding the riffle section which was under observation. The number of insects emerging immediately decreased as species dependent on a lotic environment were destroyed or forced to migrate. A few species were able to tolerate the new ecological conditions while a numerically small group of species typically found in quiet water entered the area. In the third season the lentic nature of the habitat was continued and the change in the fauna was more complete since the total population approximated that of a slow-flowing, silted stretch of the stream.

INTRODUCTION

The data presented in this paper were obtained unexpectedly in connection with a more extensive stream survey carried out on Mud Creek, Algonquin Park, Ontario, during the last 3 years to determine the qualitative and quantitative distribution of insects in the stream. The conditions reported upon were established in the course of the investigation by the normal inhabitants of the environment and present what may be termed a natural field experiment.

Mud Creek flows along a wide valley flanked by hills which reach an altitude of 1,600 feet, and empties into the Madawaska River, one of the main tributaries of the Ottawa River. The stream averages 12 feet in width throughout most of the summer and possesses many long, shallow riffle sections where the water flows rapidly over gravel, rubble or bed rock, terminating in each instance in deep, slow-flowing, silted pools. The water is slightly acid which is typical of most of the waters found in this Precambrian Shield area. The surrounding country was swept by an intensely devastating forest fire in 1914, which left this portion landmarked by charred rampikes jutting among the new growth of poplar and birch. Beaver dams and ponds are of fre-

[1]This research has been assisted by a grant from the National Committee on Fish Culture of the National Research Council of Canada, to whom the author is deeply indebted.

quent occurrence along the course of the stream, in some sections the latter entirely supplanting the riffles.

In 1938 a field station designated as No. 3 was established in one of the riffle areas and the insect population present was determined. The station was re-established in 1939 in the same position, and up to the end of June the physical nature of the stream here corresponded closely in the two seasons, but early in July beavers constructed a dam across the stream 100 yards below the site of the station. This brought about an immediate change in the physical character of the aquatic environment for almost 200 yards above the dam. This new condition was quite perturbing since it was hoped that a check on the results of the 1938 data could be obtained. Consequently attempts were made to discourage the beavers by breaking a large hole in the dam every day. It soon became evident that this procedure was of no avail and the dam was left relatively undisturbed for the duration of the investigation. The insect emergence was sampled as usual to discover if any significant changes arose which could be correlated with the newly imposed ecological conditions. The results were so marked that the investigation was carried on again in 1940 to cast further light on the problem.

Method

The method used in this survey was identical with that used by Ide (1940) in similar stream surveys for the past few years. A trap or cage consisting of a wooden framework measuring 1 yard in all dimensions, the top and sides of which were covered with 15 mesh to the inch copper screening, was placed in an upright position in the stream covering 1 square yard of bottom. The screening constituting the sides extended well below the water surface but did not come into direct contact with the bottom particles. Thus insects emerging from the water surface covered by the cage were captured while the immature stages were free to move into or out of the area. The trap was visited daily at approximately the same time and completely cleared of the insects which had emerged from the enclosed water surface in the preceding 24-hour interval. The collections were preserved in alcohol and retained for identification.

Physical and Chemical Changes in the Environment

The most significant changes in the aquatic environment at the station arose in the physical nature of the stream following the construction of the beaver dam and were directly related to the flooding of the area brought about by the retention of water at the dam. As the beavers increased the height of the dam, the amount of water held back increased correspondingly and flooded farther and farther upstream until finally the riffle which was under observation was completely obscured.

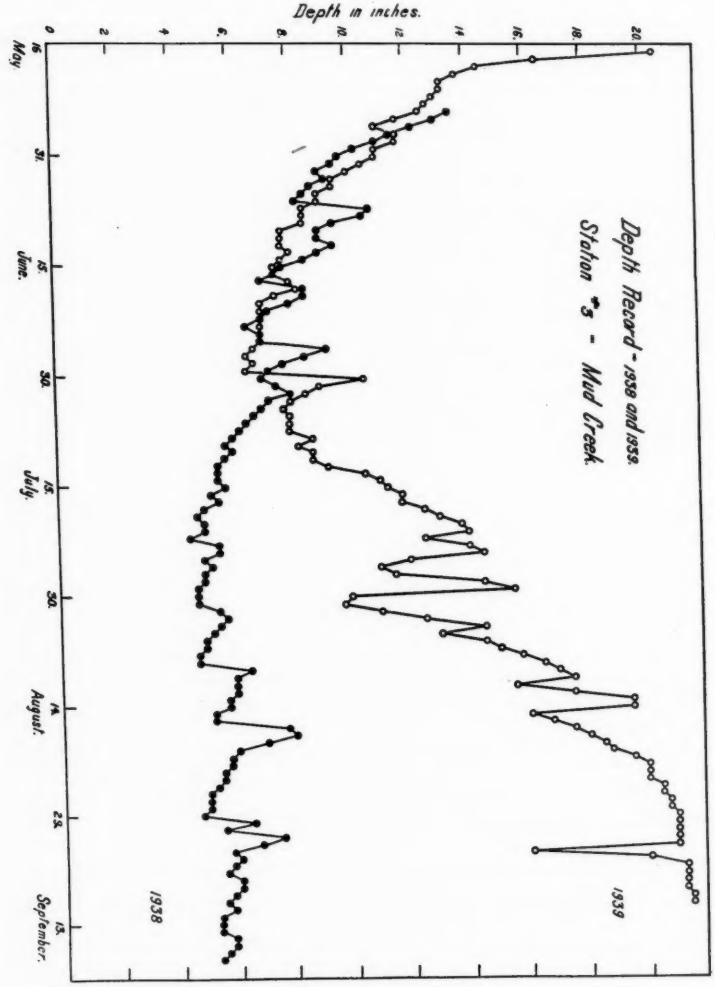

Figure 1.—Seasonal variation in the depth of water at station No. 3, Mud Creek, for the years 1938 and 1939

The depth of water at the station was recorded daily from a graduated stake driven into the stream bed, and these records are illustrated for the first two seasons in Figure 1. In 1938 the water depth decreased continually from the latter part of May to the middle of July with the exception of occasional increases brought about by local rainfall. From the middle of July to the middle of September the depth remained fairly constant averaging 5½ inches. In 1939 the water depth decreased in a similar manner up until the end of June, at which time the depth began to increase, gradually reaching 21½ inches by the middle of September. In this latter period the water level was lowered at intervals by breaking a hole in the dam in order to facilitate collecting at the station. In 1940 the depth averaged 22 inches throughout the season and showed only minor fluctuations.

A decrease in the rate of flow of water at the station accompanied the increase in depth. In each season the rate was greatest in the early part of the year as a result of the spring flood and decreased continually throughout the remaining months. The average rate of flow of water in the first season was 1.2 feet per second. In the second season the average value dropped to 0.5 feet per second and throughout most of the last season the rate was too small to be satisfactorily measured.

Directly associated with the decrease in the rate of flow of water at the station which followed the construction of the beaver dam there occurred a noticeable deposition of sand, silt and other particulate matter, brought about as a result of the reduced transport power of the water. The interstitial spaces among the rubble gradually became filled with the heavier materials and the rocks covered with a thin layer of silt.

The temperature of the water at the station was recorded continuously throughout the investigation by means of a Negretti and Zambra distance recording thermometer. Although the climatic conditions varied considerably in the three seasons during the spring period, which brought about apparent discrepencies in the comparison of temperatures at this time, the actual accumulated temperature up to any particular date in the summer showed little difference from year to year. On account of the increased depth of water at the station in the latter part of 1939 and throughout 1940 the daily temperature fluctuations in this period were not as great as in the preceding part of the investigation.

A slight decrease in the oxygen content of the water was recorded following the introduction of lentic conditions at the station and a slight increase in the total carbonate content. The values in both cases, however, did not appear to approach a lethal level with respect to the biota present.

Quantitative Change in the Insect Fauna

The numbers of insects that emerged into the trap at station No. 3 during the course of the survey are tabulated in Table 1 as monthly totals. The main aquatic insect orders are treated in separate columns with the exception of the Diptera which are subdivided into the family Chironomidae and a miscellaneous group which is comprised mainly of the families Tipulidae, Empidae and Simuliidae. Only male individuals of the last family have been included in the quantitative data since large numbers of females are carried into the cage on the body of the collector during the peak of their emergence and thus constitute a considerable source of error when quantitative results are considered.

From Table 1 it is evident that the total number of insects that emerged during the months June to August, inclusive, was greatest in 1938 when a running water habitat prevailed at the station, decreased in 1939 when still water conditions were introduced and reached the lowest value in 1940 when the lentic nature of the environment had become more firmly established. In July and August, 1939, and throughout the complete 1940 season the Ephemeroptera, Trichoptera, Plecoptera and miscellaneous group showed a distinct decrease in numbers while the Chironomidae showed an increase when the monthly totals are compared with those obtained in 1938.

Table 1.—Monthly totals of the number of insects that emerged at station 3 during the summer months of 1938, 1939 and 1940

	Item	Ephemeroptera	Trichoptera	Plecoptera	Chironomidae	Miscellaneous	Total
Lentic	1938						
	June	1,201	54	18	714	56	2,043
	July	1,744	72	76	515	64	2,471
	August	92	323	22	474	15	926
							5,440
	Percentage of the total population	55.8	8.3	2.1	31.3	2.5	.....
Beaver dam	1939						
	June	1,214	36	36	710	46	2,042
	July	931	47	4	1,020	39	2,041
	August	68	10	2	584	11	675
							4,758
	Percentage of the total population	46.5	2.0	0.9	48.6	2.0	.....
Lotic	1940						
	June	313	30	6	776	5	1,130
	July	141	36	1	1,560	4	1,742
	August	14	35	..	891	4	944
							3,816
	Percentage of the total population	12.3	2.7	0.2	84.4	0.4	.....

The month of June in the first two seasons is the only period in which an annual comparison of the emergence can be made while lotic conditions were prevalent at the station. The total insect emergence

for this month, 2,043 individuals in 1938 and 2,042 in 1939, as well as the separate group totals correspond closely. Thus it seems improbable that the effect of annual variation in the insect emergence is of sufficient magnitude to account for the numerical decrease which occurred following the advent of the beaver dam.

The significance of the quantitative change in the insect population can be pointed out more readily if each group is represented as a percentage of the total emergence for the season and these values compared in the respective years (Table 1). The Ephemeroptera constituted the dominant group in 1938 composing 55.8 per cent of the insects obtained but fell into second place from the standpoint of abundance in 1939 and 1940 composing 46.5 per cent and 12.3 per cent, respectively. In a similar manner the Plecoptera decreased from 2.1 to 0.9, to 0.2 per cent, respectively, and the Miscellaneous group fell from 2.5 per cent in the first season to 2.0 per cent in the second, and 0.4 per cent in the third season. The Trichoptera decreased from 8.3 per cent in 1938 to 2.0 per cent in 1939 and thence increased slightly to 2.7 per cent in 1940. Conversely the Chironomidae showed a continual increase in numbers rising from second position from the standpoint of relative abundance at 31.3 per cent in 1938 to the dominant position represented by 48.6 per cent in 1939 and finally constituted 84.4 per cent of the total insect population in 1940.

With respect to the productivity of this area, the weights or volumes of the daily collections exhibit a more marked decrease than is indicated in the numerical data above. Both the immature and adult stages of the Ephemeroptera, Trichoptera and Plecoptera groups which account for most of the decrease in numbers are heavier and larger forms than the corresponding stages of the Chironomidae which is the only group that was augmented following the construction of the beaver dam.

Qualitative Change in the Insect Fauna

There was a distinct qualitative change in the insect fauna recorded at the station following the construction of the beaver dam and this was to a large extent responsible in bringing about the quantitative change discussed above. In order to determine this change individuals belonging to the orders Ephemeroptera, Trichoptera and Plecoptera were determined to species wherever possible. All other specimens were identified only to family so that the complete qualitative change cannot be estimated.

The insect species have been placed in three main types, based on their reaction to the conditions introduced at the time of the flooding, in order to clarify the discussion. Type 1 includes those that were reduced numerically or completely wiped out of this section of the stream after the beaver dam was constructed and represents typical

rapid water dwellers that were unable to withstand the still water conditions. In this category are included species that emerge early in the season so that no change was apparent in 1939 but were absent in 1940; species that emerge in the mid-part of the summer and thus showed a drop in numbers after July 1, 1939, and were absent in 1940; and lastly species that emerge late in the summer and were present only in 1938. Type 2 includes those species that showed no appreciable change in either 1939 or 1940 as compared with 1938 and thus represent tolerant forms that were able to exist equally well in a lotic or lentic environment. Type 3 includes those species that were recorded only in the period following the flooding and is made up entirely of typical still water forms that were unable to gain a foothold at the station while lotic conditions existed there.

The species obtained at the station, the number captured in the cage each season and the type to which they belong are listed in Table 2. A few species are of doubtful position because of the paucity of individuals taken and these are placed in the type to which they appear to belong followed by a question mark.

A total of 14 species of Ephemeroptera belong to Type 1, 7 to Type 2 and 7 to Type 3. Ten species of Trichoptera fall into Type 1, 7 into Type 2 and 3 into Type 3. Of the Plecoptera 9 species belong to Type 1, 1 to Type 2, while there was no representative of this order belonging to Type 3. Totalling the results for these three orders, 33 species present at the station in 1938 were reduced in numbers or completely wiped out of this area following the construction of the beaver dam, 15 were able to tolerate the new ecological conditions and 10 species were introduced at the station as a result of the changed environment.

A few apparent discrepencies may be noted in Table 2 with respect to the type in which certain species have been placed. In these instances a more thorough knowledge of the habits of these forms has been used in conjunction with the numerical data to determine the type to which they belong. Within each type the species included exhibit a gradation between the extremes delimiting the type which may be significant from an ecological viewpoint. For instance, it is probable that within a rapid water community some species utilize only the still water micro-habitats found in the lee of rocks so that these forms although representing Type 2 would tend to increase when lentic conditions spread over this whole section of stream; conversely, some species which are more dependent on current could utilize the flowing water micro-habitats found in a pool but would become reduced numerically since the reduction of the available lotic areas would necessitate the maintenance of a smaller population.

In 1938 the fauna represented at the station consisted in its entirety of forms typically associated with a running water habitat. In 1939 most of these species were recorded again although, as has been shown in Table 2, many were reduced in numbers after July 1 and others

Table 2.—The number of individuals of each species recorded at Station 3, during the period June 1 to August 31, 1938, to 1940, inclusive

Item	1938	1939	1940	Type
EPHEMEROPTERA				
Baetis cingulatis	4	15	..	1
Baetis flavistriga	163	50	..	1
Baetis parvus	1	..	..	1(?)
Baetis pluto	47	20	1	1
Baetis pygmaeus gr.	130	32	1	1
Leptophlebia deblis	50	29	1	1
Leptophlebia guttata	3	4	..	1
Leptophlebia mollis	112	51	1	1
Leptophlebia volitans	19	53	7	2
Heptagenia hebe	6	7	..	1
Heptagenia pulla	111	26	1	1
Epeorus humeralis	2	..	..	1(?)
Stenonema canadense	38	50	38	2
Stenonema fuscum	30	41	25	2
Stenonema rubromaculatum	9	2	28	2
Stenonema vicarium	1	5	5	2
Habrophlebia vibrans	2,297	1,798	311	2
Ephemerella bicolor gr.	4	1	4	2
Ephemerella invaria	1	..	..	1(?)
[1]*Ephemerella subvaria*	..	..	1	(?)
[1]*Brachycercus sp.*	2	..	..	(?)
[1]*Siphlonurus alternatus*	1	..	..	(?)
Pseudochloeon carolina	5	5	..	1
Centroptilum convexum	..	1	26	3
Centroptilum semirufum	..	1	2	3
Centroptilum simile (?)	1	8	..	1
Chloeon minor	..	..	2	3(?)
Chloeon rubropictum	..	1	4	3
Chloeon triangulifer	..	9	9	3
Choroterpes basalis	..	1	..	3(?)
[1]*Baetisca laurentina*	..	1	..	(?)
[1]*Blasturus sp.*	..	2	1	3(?)
TRICHOPTERA				
Chimarrha aterrima	352	12	..	1
Philopotamus distinctus	13	..	..	1
Cheumatopsyche pettiti	25	20	1	1
Hydropsyche betteni	13	2	..	1
Hydropsyche sparna	17	..	..	1
Rhyacophila carolina	5	1	..	1
Rhyacophila fuscula	2	..	..	1(?)
Agapetus sp.	..	2	1	2(?)
Psychomyia diversa	4	1	..	1
Psychomyiella flavida	2	..	1	2(?)
Polycentropus confusus	8	30	5	2
Plectrocnemia cinerea	1	5	14	2
Nyctiophylax vestitus	3	9	21	2
Lepidostoma sp.	1	2	..	1(?)
[1]*Goera stylata*	..	..	1	(?)
Oxyethira sp.	1	..	1	2(?)
Athripsodes dilutus	2	3	13	2
Athripsodes angustus	..	6	..	1(?)
Oecetis inconspicua	..	..	8	3
Mystacides sepulchralis	..	..	8	3
Stenophylax guttifer	..	..	27	3
PLECOPTERA				
[2]*Leuctra decepta* *Leuctra hamula* *Leuctra sibleyi* *Leuctra tenuis*	105	18	1	1
Nemoura venosa	1	..	..	1(?)
Hastoperla brevis	3	5	..	1
Alloperla imbecilla	..	2	..	1(?)
Isoperla montana	2	2	..	1
Isoperla sp.	5	11	5	2
Isoperla truncata	..	4	..	1
[1]*Acroneuria lycorias*	..	..	1	(?)

[1]Species represented by adult females alone; probably washed into the cage during oviposition.

[2]The genus *Leuctra* is treated as a unit since the female individuals could not be satisfactorily separated taxonomically.

which emerged late in the season were absent. Along with these forms a few species which are normal inhabitants of still water areas were taken at the station in the latter part of the summer. The introduction of these species must have been brought about by migration of individuals that were present in the quiet water along the riffle margins and in the pools, into the sampled section of the stream once the lentic conditions spread over this portion. The predominant migrant group was the Ephemeroptera which were apparently able to migrate more readily than the Trichoptera which may be impeded somewhat by their cases and fixed habit. No new Plecoptera were taken and this is as would be expected since these forms are almost exclusively rapid-water dwellers. In 1940 the change had progressed further and with the exception of an occasional single individual of a species the total population consisted of forms commonly associated with a still-water habitat. The result of oviposition in 1939 would be an important factor in establishing a more stable lentic population in 1940 since the lack of riffles in this section of the stream would favour the oviposition of still-water species.

There was a net decrease in the emergence after the beaver dam was constructed, since the loss of the truly lotic species from this area more than offset numerically, the gain brought about by the newly introduced lentic forms. From the results of another investigation on the emergence of aquatic insects from different types of bottom in Mud Creek it has been found that rubble in a rapid stretch of stream is more productive from the standpoint of insects than is the mucky bottom found in pools. Comparable results have been obtained by other investigators such as Needham and Pate who found that pool bottoms produced only one-third as much weight of potential trout food as did a rubble bottom (Needham, 1938). Thus it seems improbable that the lentic fauna would at any time approach the fauna that was found at the station during the period of lotic conditions unless a growth of aquatic plants were to arise thereby causing an increase in the lentic fauna.

A few of the actual emergence polygons of the species found at Station 3 are recorded graphically in Figure 2. These illustrate both the quantitative and qualitative change in the insect fauna which followed the building of the beaver dam. Representing what has been referred to above as Type 1 are the species *Baetis flavistriga, Chimarrha aterrima* and the genus *Leuctra,* including the species *sibleyi, hamula, tenuis* and *decepta,* which has been recorded as a unit since the female individuals could not be distinguished satisfactorily. In all three instances the general correspondence in the emergence up until July 1 in 1938 and 1939 is evident as is the decrease in the period after July 1, 1939. *Stenonema canadense, Polycentropus confusus* and a species tentatively listed as *Isoperla* sp. are representative of Type 2. It is apparent in Figure 2 that these species were not noticeably affected by the altered conditions found at the station after July

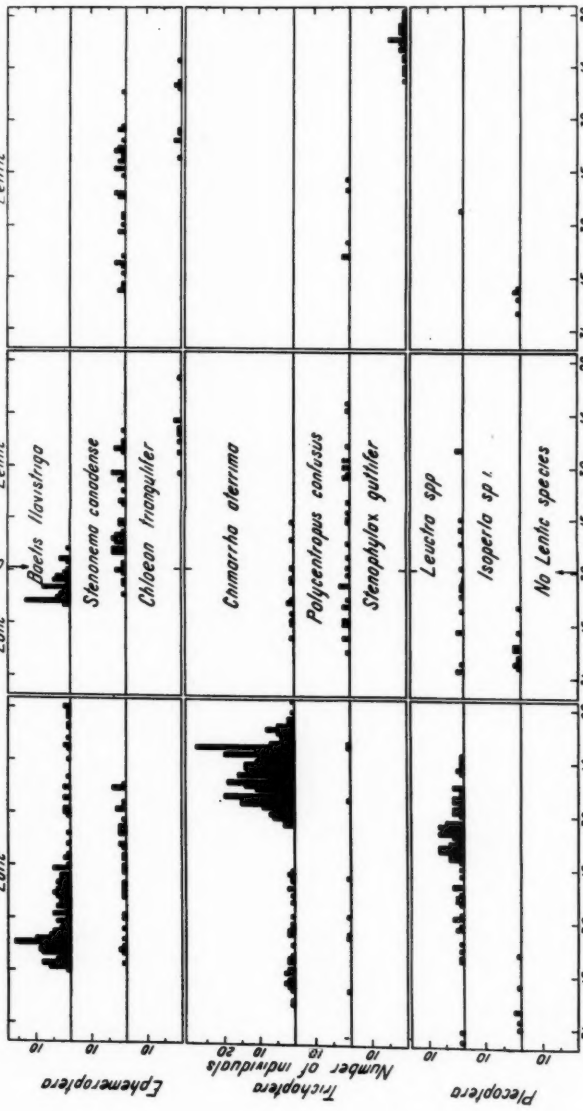

Figure 2.—Actual emergence polygons of a few representative species which occurred at Station 3

1, 1939. The relation is not so clear in the case of *Polycentropus confusus* since this form seems to have dropped off considerably in 1940 as compared with 1939. However, the emergence in 1940 approximates more closely that of 1938 and it is probable that the 1939 figure merely indicates a more favourable set of conditions for this species bringing about a large annual variation. The remaining panels in Figure 2 are examples of Type 3. *Chloeon triangulifer* was present both in the latter part of 1939 and in 1940 and illustrates a form which likely migrated into the area in the former season; *Stenophylax guttifer* on the other hand represents a form which was not able to migrate into the area in 1939 and was only present in 1940 following the altered oviposition instigated in late summer of the 1939 season.

The most important single factor affecting the insect fauna at the station following the construction of the beaver dam appeared to be the decrease in the rate of flow of the water. In the light of recent investigation it has become evident that the current is of fundamental importance to insects dwelling in rapids (Wingfield, 1939). In these forms the inherent demand is not a high dissolved oxygen content as formerly held, since this is generally well above the lethal point in all lotic environments, but rather a definite flow of water causing a circulation about the individual which brings fresh oxygenated water to its body surface and also breaks down the diffusion layer of carbon dioxide in contact with it. The gills are important respiratory organs in the burrowing Ephemeroptera but in other forms are used for the most part in a mechanical way to produce a current and are important respiratory agents only under adverse conditions such as when the oxygen content falls to an extremely low level. This would account, to a large extent, for the marked depletion of the typical lotic fauna after July 1, 1939. Further, certain of these forms, such as the net building Trichoptera larvae, are dependent on the current for their food supply and many of these were found on the rocks in the spring of 1940, in which development had ceased at various immature stages reached during the preceding summer.

In a like manner the current would be the most important limiting factor preventing the appearance of normal still water inhabitants in the rapid water sections. The lack of adaptations in the former species for maintaining their position in running water would restrict these forms to still water habitats.

Summary

1. When a section of stream characterized by rubble bottom and a rapid flow of water was changed into a slow flowing pool through flooding by a beaver dam a net numerical decrease in the insect population resulted in the period immediately following the change.

2. The Ephemeroptera, Trichoptera, Plecoptera and miscellaneous Diptera groups were decreased in numbers while the Chironomidae were increased.

3. Species dependent on lotic conditions were reduced in numbers or wiped out of the area completely following construction of the dam while species typically associated with lentic conditions were introduced. A few more tolerant forms were not significantly altered.

4. In the period immediately following the advent of the dam some still water forms migrated into the area but a more stable quiet water population was established the following year as a result of successful oviposition in the latter part of the previous season.

5. The change in the insect population was correlated with the decreased rate of flow of water and the physical factors associated with this such as increased depth and deposition of sand and silt which filled the interstitial spaces on the rubble bottom as a result of the flooding brought about by obstruction of the stream.

Acknowledgments

This study was carried out at the Ontario Fisheries Research Laboratory which provided funds and facilities for the field work. The author would like to take this opportunity of thanking the members of the laboratory for their assistance throughout the investigation and to express sincere thanks to Dr. F. P. Ide, whose guidance in the field and active cooperation in the identification of the material collected has made this paper possible.

The value of the study has been enhanced through the work of Dr. T. H. Frison and Dr. H. H. Ross of the Illinois Natural History Survey, who identified the species obtained belonging to the groups in which they are specialists.

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Discussion

Mr. Harkness: I assume there are trout in this stream; do you know enough about the food of the trout to know how the beaver dam would affect the food of the trout as a whole? Would it diminish it?

Mr. Sprules: Up to the present time I have not been able to carry out a volumetric analysis of my material. Trout are present in the stream, as you suggest, but only in the early part of the season, after which time they are forced to migrate downstream due to high temperatures. I certainly believe that al-

though the numerical increase is not perhaps overly significant, the volumetric changes are of significance. Those that were wiped out were large forms, by volume and weight, while the Chrionomidae, which are increasing, are smaller. The trout would certainly have to take many more chironomids to make up a suitable diet in comparison with mayfly, stonefly and caddisfly foods.

THE PRESIDENT: Do you know how long the chironomids and mayflies remain as larvae before they emerge?

MR. SPRULES: For the most part they have a 1-year cycle. Some of the larger stoneflies and caddisfly groups have a 2-year cycle, but these did not occur in the situation investigated.

DR. IDE: Can Mr. Sprules say whether a balance was reached in the one season?

MR. SPRULES: I think not. Once the lentic conditions are more firmly established in the years to come, plant growth should occur, and this should somewhat increase the invertebrate fauna.

MR. PAUTZKE: Was any evaluation made as to the effect of the constant flow of water upon the organisms below the dam?

MR. SPRULES: At the particular point I was investigating the creek is approaching the lake into which it empties, and from there on the bottom was gravel and sand. I could not, therefore, obtain a proper comparison of the rubble nature of the bottom which I had investigated in the 1938 season.

THE RESULTS OF PLANTING BROOK TROUT OF LEGAL LENGTH IN THE SALMON TROUT RIVER, NORTHERN MICHIGAN[1]

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ABSTRACT

A creel census and tagging study was conducted on the Salmon Trout River in northern Michigan for a 3-year period to determine the most effective method of planting 7- to 9-inch brook trout. The creel census indicated that the fishing load was relatively light and that the average yield in the different years varied from 4.3 fish to 5.2 fish per rod per 4-hour day. Recoveries of jaw-tagged brook trout planted in the fall and in the spring of 3 succeeding years showed that a maximum of 1.0 per cent of fall-planted fish was returned to the fisherman's creel, and that a maximum of 19.6 per cent of spring-planted fish was returned. Tagged fish were returned throughout the entire season instead of being exhausted during the first few weeks. The movements of planted fish were not extensive but had a tendency to be downstream. In three successive seasons hatchery-reared trout contributed 44.0 per cent, 38.6 per cent, and 24.9 per cent, respectively, of the total catch.

INTRODUCTION

A number of observations have been made on the results of planting 7- to 9-inch brook trout in heavily fished streams. Hazzard and Shetter (1939), Cobb (1933), Nesbit and Kitson (1937), Hoover and Johnson (1938), and others, have conducted investigations on public waters with varied ecological conditions and fishing loads. During the summers of 1938, 1939, and 1940 a series of experiments was made to determine the effectiveness of planting adult brook trout (*Salvelinus fontinalis*) in the Salmon Trout River which runs through Marquette County, northern Michigan. The investigation was confined to the 11.3 miles of stream lying between the junction of the two principal tributaries and the outlet into Lake Superior (Fig. 1). This area lies within the lands owned by the Huron Mountain Club where fishing is limited exclusively to the club members and their guests. The restricted and closely controlled fishing made possible a complete creel census with a prompt return of all marked fish.

The river, which has an average width of approximately 30 feet, falls rapidly from a high table-land to the level of Lake Superior. Two impassable falls and two dams restrict the movement of fish through the area under investigation. The bottom soil in the upper stretches is ledge-rock and boulder but changes gradually to gravel and sand as the outlet is approached.

[1]The materials on which this study is based were included as a part of a doctoral dissertation presented to the Department of Zoology of the University of Michigan.

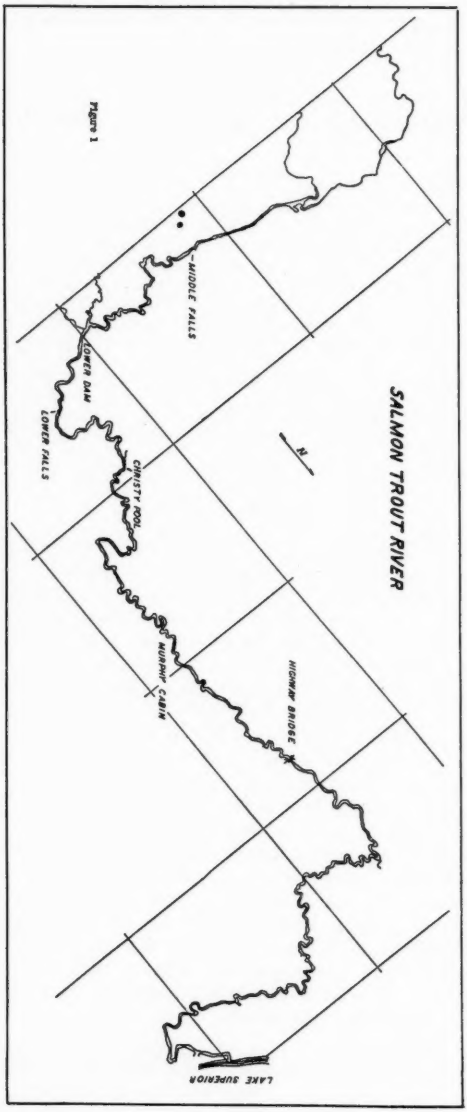
SALMON TROUT RIVER
MIDDLE FALLS
LOWER DAM
LOWER FALLS
CHRISTY POOL
MURPHY CABIN
HIGHWAY BRIDGE
LAKE SUPERIOR
N

FIGURE 1

For convenience of operation the river was divided into the following seven sections, delimited by natural barriers, varying in ecological conditions, and constituting naturally distinct fishing areas: Section 1, 0.73 miles between the junction of the tributaries and the barrier known as Middle Falls; Section 2, 1.31 miles between Middle Falls and the Lower Dam; Section 3, 0.57 miles between the Lower Dam and the Lower Falls; Section 4, 0.75 miles between the Lower Falls and Christy Pool; Section 5, 2.05 miles between Christy Pool and Murphy Cabin; Section 6, 1.26 miles between Murphy Cabin and the Highway Bridge; and Section 7, 4.50 miles between the Highway Bridge and Lake Superior. All parts of the river are quite accessible except the lower 2 miles of Section 7 which lie in a tag-alder swamp.

The Fishing Load

A complete creel census was kept during the 1938, 1939, and 1940 fishing seasons and the returns summarized by weekly intervals (Table 1). Annual summaries were made also for each section of the river to determine the relative productivity of different fishing areas (Table 2). During the 1938 season, 242 fishermen caught 1,049 brook trout from the whole river at an average rate of 4.33 fish per rod per 4-hour day. In the 1939 season 290 fishermen caught 1,421 brook trout from the same area at the average rate of 4.90 fish per day, and in 1940, 1,087 fish were caught by 209 anglers at the rate of 5.2 fish per day. The season's yield per fisherman day ranged from 8.7 to 2.3 in different sections while the average yield from the whole river for weekly intervals declined gradually throughout the season reaching its low point during the last week in 2 of the 3 years. Although the study of the data for each section for each week (tabulation not given here) showed that the seasonal decline was influenced to some degree by a shifting of the fishing load in August to less productive stretches of the river, the decline reflects also the depleted stock and poorer fishing condition usual in late summer.

Average yields of fish for a given unit of effort were appreciably higher from the Salmon Trout River than from most of the streams reported in the literature. This higher return may be correlated with the relatively light fishing load.

The Return of Legal-Length Trout Marked and Planted at Different Seasons

Large plantings of legal-length brook trout had been made in the club-owned waters of the Salmon Trout River for several years prior to 1938 without materially affecting the average catch of fish. In order to check the efficiency of the stocking procedure and to devise more successful stream-management policies, fish were marked and planted at different seasons. Previous to the investigation all the fish

Table 1.—Creel census of the Salmon Trout River for the seasons 1938, 1939, and 1940, summarized by weekly intervals

Item	Year	Period within season										Total or average
		Up to July 1	July 2-8	July 9-15	July 16-22	July 23-29	July 30-Aug. 5	Aug. 6-13	Aug. 14-20	Aug. 21-27	Aug. 28-Sept. 4	
Total fish	1938	22	154	81	218	125	102	77	60	132	78	1,049
	1939	146	94	122	196	147	134	198	180	114	90	1,421
	1940	33	179	111	205	136	124	152	66	34	47	1,087
Total fisherman days	1938	4	21	16	34	20	31	25	21	37	33	242
	1939	22	14	18	28	23	27	42	43	38	35	290
	1940	9	21	15	22	26	25	32	22	17	20	209
Yield per rod per day	1938	5.5	7.3	5.1	6.4	6.3	3.5	3.1	2.9	3.6	2.4	4.3
	1939	6.6	6.7	6.7	7.0	6.4	5.0	4.7	4.2	3.0	2.6	4.9
	1940	3.7	8.5	7.4	9.3	5.2	5.0	4.8	3.0	2.0	2.4	5.2

Table 2.—Creel census of the Salmon Trout River for the seasons 1938, 1939, and 1940, summarized by sections

Item	Year	Section No.								Total or average
		1	2	3	4	5	6	7	Unknown[1]	
Total fish	1938	22	307	163	175	94	122	117	49	1,049
	1939	108	326	159	253	98	254	180	43	1,421
	1940	113	198	192	182	25	158	159	60	1,087
Total fisherman days	1938	5	55	32	43	34	31	25	17	242
	1939	14	52	30	59	28	58	39	10	290
	1940	13	30	24	42	11	37	41	11	209
Yield per rod per day	1938	4.4	5.6	5.1	4.1	2.8	3.9	4.7	2.9	4.3
	1939	7.7	6.3	5.3	4.3	3.5	4.4	4.6	4.3	4.9
	1940	8.7	6.6	8.0	4.3	2.3	4.3	3.9	5.5	5.2

[1]Exact location of catch not recorded.

planted in the river were released in the fall of the year. During the progress of the work some fish still were planted in the fall, but the majority were released in May and June. Of the 11,116 7- to 9-inch brook trout planted during 1938, 1939, and 1940 (Tables 3, 4, 5, 6 and 7) 3,884 were marked with Monel-metal jaw tags similar to those described by Shetter (1936).

The percentage of tagged brook trout recovered by anglers varied widely, depending upon the season in which the fish were planted and the intensity of fishing. Of 252 tagged brook trout released in Sections 2, 3, and 6 during the spring of 1938 (Table 3) 39, or 15.5 per cent, were returned the same season and none the next year. In November, 1938, 1,233 brook trout were tagged and planted in Sections 2, 3, and 6 (Table 4). The following season only three, or 0.02 per cent, were recovered by fishermen. Although this extremely low recovery may have been influenced to some extent by a hard winter and severe spring floods, the high mortality is believed to have been largely due to the natural inability of the trout to survive over the winter. This inability seems to be characteristic of most hatchery-reared trout (Nesbit and Kitson, 1937; Cobb, 1933; Hewitt, 1938; Shetter and Hazzard, 1940).

In the spring of 1939, 600 fish were tagged and planted on May 16, and 500 were marked and planted on June 22 (Table 5). Of the first group 21.9 per cent were recovered, and of the second group 16.6 per cent were recovered during the season. The average recovery for the entire spring planting was 19.6 per cent. The percentage of tagged fish recovered from plantings made in different sections of the river varied from 13.5 per cent to 25.2 per cent; this variation reflected to some degree the differences in the intensity of fishing. Of 600 fish tagged and planted in October, 1939, only 1.0 per cent were returned the following season (Table 6). This small return suggests an over-winter mortality comparable to that suffered by fish planted in the fall of 1938.

Table 3.—Recovery and migration of brook trout planted on May 26, 1938

Location	Total number planted	Total number tagged	Total number of tagged fish recovered[1]	Percentage of tagged fish recovered	Percentage migrating downstream	Percentage migrating upstream	Percentage remaining where planted
Section 2.....	750	71	7	9.8	42.9	0.0	57.1
Section 3.....	750	33	9	27.3	44.5	33.3	22.2
Section 6.....	1,500	148	23	15.3	0.0	47.8	62.2
Total or average	3,000	252	39	15.5	17.9	36.0	46.1

[1]Recovered in summer, 1938; none recovered in 1939.

Table 4.—Recovery of brook trout planted on November 12, 1938

Location	Total number planted	Total number tagged	Total number of tagged fish recovered[1]	Percentage of tagged fish recovered
Section 2	400	375	0	0.0
Section 3	350	350	3	0.85
Section 6	750	508	0	0.0
Total or average.....	1,500	1,233	3	0.02

[1]Recovered in summer, 1939. All recoveries were made at location of planting.

A total of 699 trout were tagged and planted in Sections 1, 2, 3, 6, and 7 in the spring of 1940 (Table 7). Of the 500 released on May 1, 17.2 per cent were recovered during the current season, while the 199 released on June 19 showed a return of 13.0 per cent by the close of the season. The average return from the whole spring planting in 1940 amounted to 16.0 per cent of the total. None of the spring-planted fish from any season wintered over to be returned the following year.

From the foregoing data it is quite obvious that spring plantings of 7- to 9-inch brook trout give results far superior to the best fall plantings, and that in the area studied only spring and summer stocking is justified.

Table 5.—Recovery and migration of brook trout planted in the spring of 1939

Location	Date of planting	Total number planted	Total number tagged	Total number of tagged fish recovered	Percentage of tagged fish recovered[1]	Percentage migrating downstream	Percentage migrating upstream	Percentage remaining where planted
Section 1.....	June 22	450	200	27	13.5	33.3	0.0	66.7
Section 2.....	May 16.....	700	400	102	25.2	31.4	3.9	64.5
	June 22	90	0	0	0.0	0.0	0.0	0.0
Section 3.....	May 16.....	600	200	31	15.5	26.6	6.6	66.8
Section 4.....	June 22	360	200	31	15.5	6.25	0.0	93.75
Section 6.....	June 22	450	100	25	25.0	40.0	12.0	48.0
Section 7.....	June 22	150	0	0	0.0	0.0	0.0	0.0
Total or average.....	May 16.....	1,300	600	133	21.9	30.1	5.01	64.89
Total or average.....	June 22	1,500	500	83	16.6	25.8	3.6	70.60
Grand total or average..	.....	2,800	1,100	216	19.6	28.2	4.16	67.64

[1]Recovered in the summer of 1939; none recovered in 1940.

Table 6.—Recovery and migration of brook trout planted on October 17, 1939

Location	Total number planted	Total number tagged	Total number of tagged fish recovered[1]	Percentage of tagged fish recovered	Percentage migrating downstream	Percentage migrating upstream	Percentage remaining where planted
Section 1	100	100	0	0.0	0.0	0.0	0.0
Section 2	450	100	3	3.0	33.0	0.0	66.0
Section 3	400	100	1	1.0	0.0	0.0	100.0
Section 4	300	100	1	1.0	0.0	0.0	100.0
Section 6	150	100	0	0.0	0.0	0.0	0.0
Section 7	100	100	1	1.0	0.0	100.0	0.0
Total or average	1,500	600	6	1.0	16.6	16.6	66.6

[1]All recoveries made during summer, 1940.

Table 7.—Recovery of brook trout planted in the spring of 1940

Location	Date of planting	Total number planted	Total number tagged	Total number of tagged fish recovered	Percentage of tagged fish recovered
Section 1	June 19	116	116	19	16.4
Section 2	May 1	675	200	30	15.0
	June 19	200	0	0	0.0
Section 3	May 1	675	200	28	14.0
	June 19	300	0	0	0.0
Section 6	June 19	100	83	7	8.5
Section 7	May 1	150	100	28	28.0
	June 19	100	0	0	0.0
Total or average	May 1	1,500	500	86	17.2
Total or average	June 19	816	199	26	13.0
Grand total or average		2,316	699	112	16.01

The Percentage of Hatchery Fish in the Catch

The large number of tagged fish returned to the fisherman's creel made it apparent that a sizable portion of the seasonal catch was contributed by the legal-length fish released in the river. Because the largest number of fish tagged in the spring was planted in 1939, the returns for that season were used as a basis for calculating the percentage of planted fish in the catch from each of the various sections. Since the migration of the planted fish influenced the population of hatchery-reared fish in every section, corrections have been made on the assumption that tagged and untagged fish migrated and were caught in the same proportions.

Different sections of the river showed a wide variation in the contribution of planted fish to the total catch (Table 8). The highest percentage of hatchery fish recorded was 61.5 per cent from Section 5. All these fish had migrated into that section where they apparently composed a large part of its population. The lowest contribution of hatchery fish was 13.3 per cent in the catch taken from Section 7 where only a small number of fish was released.

The season's catch from the whole river in 1939 contained 61.4 per cent native fish and 38.6 per cent hatchery fish planted during the current season. In the 1938 season 44.0 per cent of all fish caught

were planted and during the 1940 season 24.9 per cent of the catch was hatchery stock. These results are similar to those obtained by Hazzard and Shetter (1939) who reported that 46.9 per cent of brook trout caught in the Pine River of lower Michigan were planted as 7- to 9-inch fish, while 33.9 per cent of the entire catch of all species was hatchery stock.

Table 8.—Estimated percentage of native and hatchery fish in the catch, based on recoveries of tagged fish planted in the spring of 1939

Location	Total number planted	Total number tagged	Total catch	Total tagged fish recovered	Percentage of native fish in catch	Percentage of planted fish in catch	Percentage of tagged fish in catch	Percentage of tagged fish recovered
Section 1.....	301	134	98	18	58.7	41.3	18.4	13.4
Section 2.....	654	317	326	76	52.0	48.0	23.3	24.0
Section 3.....	485	174	159	30	47.5	52.5	18.8	17.3
Section 4.....	662	321	253	57	53.5	46.5	22.5	17.8
Section 5.....	259	69	98	16	38.5	61.5	16.3	23.2
Section 6.....	331	49	254	11	70.7	29.3	4.33	22.4
Section 7.....	108	36	181	8	86.7	13.3	4.41	22.2
Total or average..	2,800	1,100	1,422	216	61.4	38.6	15.1	19.6

Migration of Planted Fish

The migration of the planted trout was not extensive. Tables 3, 5, and 6 show the percentage of fish that moved from the location of release. Seventeen and nine-tenths per cent of all fish planted in the spring of 1938 moved downstream, 36.0 per cent moved upstream, and the remaining 46.1 per cent were caught near the point of release. In 1939 the situation was reversed with 28.2 per cent moving downstream, 4.16 per cent moving upstream, and 67.64 per cent remaining where released. The 1939 results are considered to be more significant since they were based on a larger number of returns spread over the entire length of the river. The greatest movement recorded for a single individual was 5.26 miles downstream in 88 days. Upstream migration was limited to some extent by the natural and artificial barriers mentioned previously, but in those stretches where considerable upstream migration was possible the percentage of fish moving against the current was no greater than the average for all sections. The planted fish that wintered-over before they were caught remained for the most part in the areas where they were released.

The Rate of Return of Planted Fish

Various investigators have observed that most of the planted brook trout which are returned to the fisherman's creel are caught within 5 weeks of the time of release. Cobb (1933) found in two experiments that the greatest number of trout was taken 23 and 36 days, respectively, after liberation. Hoover and Johnson (1938) showed that in a

New Hampshire stream 99.7 per cent of all trout returned and 70.0 per cent of all the tagged trout were captured within 3 weeks. Hazzard and Shetter (1939) demonstrated that most of the brook trout recovered from plantings entered the angler's creel within 3 weeks after planting and that all appeared within 7 weeks. It will be noted from Table 9 that in the Salmon Trout River tagged fish continued to appear in the catch throughout the whole season but that the number per week tapered off gradually toward the close. The lack of early returns from the June plantings was correlated with the extremely light fishing load in the areas where these fish were stocked. For the entire 13 weeks of the 1939 fishing season hatchery fish contributed substantially to the total catch. Approximately the same rate of return occurred during the 1940 season. It is possible that the relatively light fishing throughout the entire area accounts for the fact that the hatchery fish were caught throughout the season instead of being exhausted completely within the first few weeks.

Table 9.—The rate of return by weekly periods of tagged brook trout, 1939 season

Weekly period	Return from May 16 planting (600 fish)	Return from June 22 planting (500 fish)	Total return	Percentage of total return
[1]May 30-July 1	60	0	60	27.8
July 2-8	13	0	13	6.2
July 9-15	18	15	33	15.2
July 16-22	10	21	31	14.4
July 23-29	4	5	9	4.1
July 30-Aug. 5	9	7	16	7.4
Aug. 6-13	3	11	14	6.5
Aug. 14-20	7	11	18	8.3
Aug. 21-27	4	14	18	8.3
Aug. 28-Sept. 4	2	2	4	1.8
Total	130	86	216	100.0

[1]All fishing during this period was done on May 30, 31, June 1, and June 28, 29 and 30.

Acknowledgments

The author wishes to thank C. H. Hodges, Jr., and Wetmore Hodges for their sponsorship of the investigation, the membership and management of the Huron Mountain Club for their assistance and cooperation in supplying records of the catch and recoveries of tags, Drs. Carl L. Hubbs, Albert S. Hazzard, and David S. Shetter for their criticism and suggestions during the progress of the study, and F. W. Taber for assistance in field work.

Summary

1. A creel census conducted on the Salmon Trout River, a private stream in northern Michigan, indicated that the fishing load was relatively light and that the yield per rod per day was above the average for public waters.

2. Jaw-tagged brook trout, 7 to 9 inches long, were planted in both spring and fall. Fall planting showed a maximum return of 1.0 per cent, while spring planting yielded a maximum return of 19.6 per cent.

3. The migration of planted fish was limited in extent, but showed a slight downstream tendency.

4. Legal-length fish planted at the beginning of the fishing season contributed to the catch throughout the entire season.

5. The contribution of hatchery fish to the entire season's catch varied from 24.9 per cent to 44.0 per cent in different years.

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Discussion

Dr. Huntsman: Have you any evidence that the planted fish migrate down to the lake and back?

Mr. Smith: We have no evidence except that none of our tagged fish returned during the following seasons. If they moved down, the assumption would be that they would come back. The fish which come up into the stream during the late summer and fall are mostly large fish, running from 2 to 3½ pounds, and are usually 3 or 4 years old. These fish come up, spawn and run down again before the break-up in the spring. We have no evidence that any of our planted fish went downstream; if so none of them have returned during the period of our experiments.

Dr. Huntsman: Have you noticed any difference in the character of these fish? Are your planted fish of the same kind as the native fish?

Mr. Smith: Yes, the fishermen all report that they cannot tell the difference between the planted fish and the native fish. The rate of growth during the current season seems approximately the same, and their appearance is the same.

DR. HUNTSMAN: In Nova Scotia we have been following the movements of certain fish which run down to the sea in the spring, both those a few inches long and the larger ones. We have been unable to find any that stayed up the stream. The whole population moves down to tidal waters during the early part of the summer.

DR. SHETTER: It should be borne in mind by anyone who might care to apply this data to his own work that the angling pressure may influence the length of time during which the planting will affect the catch. It should be pointed out that Mr. Smith's experiments on lightly-fished streams indicate that where the fishing intensity is low the plantings of marked fish may very well last over the entire season. Fishing intensities on the Pine River, which is a public stream, often run over 300 man-hours of fishing per acre per season. At the Wingleton Club, plantings of a size equal to those on the public streams yielded catches throughout the entire trout season. A similar stocking comparable to the Pine River, and even lighter, yielded fishing on the marked fish throughout the entire season. This was probably due to the comparatively light intensity of angling.

MR. SMITH: The point is well taken. Dr. Shetter has referred to a fishing intensity of 300 man-hours per acre per season. In the stream to which I have referred the fishing intensity was 35 to 40 fisherman hours per acre per season.

THE RELATION OF REFRIGERATED LOCKERS TO CONSERVATION OF FISHERY PRODUCTS

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ABSTRACT

The use of refrigerated lockers by the housewife as a method of preservation of foods has recently become of considerable importance, and hundreds of such locker plants are now available. The use of such facilities for storage of fish can be of benefit to the sports fisherman to preserve his catch, to the frugal housewife in putting up a supply of fish when there is a surplus and prices are low, and to the commercial fishery industry as a means of distributing frozen fish in small communities where large commercial cold storage plants are not located.

As is the case in the commercial cold storage of fish, considerable care must be taken in provision of adequate storage methods for fishery products which are to be stored in refrigerated lockers in order to prevent development of such undesirable changes as freezer burn, rancidity, and discoloration of the products. Methods which are satisfactory for use in commercial freezers may not be suitable for use by the refrigerated locker patron. Freezing and packaging methods should be relatively simple and of such a nature that they can be readily applied by the individual patron to small lots of fish.

Within the past few years there has been a considerable development of the refrigerated locker industry. Lockers ordinarily ranging in capacity from 8 to 12 cubic feet and renting from $0.75 to $1.00 per cubic foot per year and held at a temperature of from 0° F. to 10° F. are now available in most sections of the country for use by the housewife for storing frozen foods. There are at present more than 1,000 such plants throughout the United States with a majority of them located in the Middle West and Pacific Coast states. These lockers have been used largely for the storage of fruits, vegetables and meats and only occasionally have fish been stored in them.

Refrigerated locker plants offer potential service to at least three groups interested in conservation of fishery products: Sports fishermen, housewives, and commercial fishermen. The sports fisherman sometimes catches more fish than he can immediately consume, and there is then the problem of what to do with the surplus fish. The refrigerated locker can be of considerable service, since fish frozen and held in the lockers can easily be kept for a period of several months, and consumed as needed. If a refrigerated locker plant is located in a resort area, vacationists can freeze and store their fish as they are caught and thus insure a fresh supply on their return home.

Perhaps the largest group interested in utilizing the lockers for fish are housewives who already have a locker for vegetables or other products. Many species of fish are of a definitely seasonal nature and when abundant on the market can be purchased for considerably less

than at other seasons. The housewife, especially if she is living along the seacoast where occasional surplus catches can be obtained, may wish to freeze fish and have them available at a later time when they are no longer in season.

The refrigerated locker industry provides a means of increasing the distribution of commercially frozen packaged fishery products in communities which are too small to have a general cold storage warehouse. In such a location, unless the retailer is provided with adequate low-temperature storage cabinets, frozen fishery products can not readily be made available to the consumer. In many localities, a frozen locker plant affords an opportunity for sale of frozen fishery products. Moreover, since the patron has available cold storage space of his own, he should be able to buy frozen fish in quantity and store it in his locker, thus effecting a substantial saving. This system is already being used for fruits and vegetables where the locker owner sells to his customers frozen products in lots of 6 packages at a saving of about 25 per cent over retail prices.

In the vast majority of the refrigerated locker plants the storage temperature is kept below 10° F. and in many it is as low as 0° F. These compare favorably with the temperatures employed in commercial cold-storage establishments. Also, many of the locker plants are equipped with sharp freezers, and in fact, several states require the inclusion of a sharp freezer in each locker establishment. The main problem in storing fish in refrigerated lockers is the method of treatment and packaging preliminary to freezing, since conditions of freezing and cold storage in lockers are essentially the same as in ordinary commercial practice. Preliminary steps such as glazing and packaging can not always be carried out by commercial methods, owing to the much smaller numbers of fish handled in the locker plants and the inexperience of locker patrons. Accordingly, the Division of Fishery Industries of the Fish and Wildlife Service at its Technological Laboratory in Seattle, Washington, has been making a study of methods of handling fish and shellfish most suitable for use in locker plants.

In commercial practice, whole fish are covered with a glaze of ice in order to protect them from evaporation and from access to the air which would cause rancidity and discoloration. The glazing operation is usually carried out by placing the frozen fish in large baskets and immersing them in cold water in tanks in the cold storage room. This process is not well-suited to small lots of fish nor is it one which could be readily carried out by the locker patrons, even if the necessary equipment were available. One of the most suitable methods for locker patrons developed to date is to place the whole fish in a rubber (latex) bag. These bags are now available for the protection of various foodstuffs in cold storage and they can be obtained by the locker plants pre-inflated to the size of the fish. All that is necessary to do is to place the fish in a bag and then immerse the bag in warm water, whereupon it shrinks to fit the fish. The open end can then be sealed by

heating or tying. Fish treated in this way are amply protected against both desiccation and oxidation. Another feasible method of protecting whole fish, which is adaptable to locker plant use, is to wrap the fish in large sheets of moisture-proof paper. If this method is used, it is necessary to employ paper which is not only grease- and water-proof, but also which will not allow moisture to evaporate through it. Thus, ordinary parchment paper, while completely water-proof, is quite inadequate and allows a great deal of evaporation to take place. Since suitable moisture- or vapor-proof paper is quite expensive, this method is apt to prove more costly than the use of latex bags, and hence the latter are preferable.

Whole fish should have the viscera removed before freezing, but the head and tail can be left on. No other preliminary treatment is required in handling whole fish.

Although the storage of whole fish represents the simplest method, requires the least attention and results in the least amount of deterioration in storage; sometimes it may be desired to store dressed fish, fillets, or steaks in order to conserve on storage space by getting rid of head, tail, bones, and other refuse. When such dressed fish or fillets are prepared, a greater area of cut flesh is exposed and unless considerable care is exercised in packaging, the storage life of the product will be materially reduced.

In dressing fish for storage in refrigerated lockers, it is recommended that the fish be cut in as large pieces as possible in order to minimize the amount of exposed surface. Thus it is advisable to prepare chunks of fish of the size which will be used for a meal, rather than to prepare individual steaks. The use of a wrapping paper which is adequately moisture- and vapor-proof is mandatory if satisfactory storage is to be attained. Ordinary waxed or parchment papers are quite unsatisfactory and special papers such as are manufactured for use with frozen foods must be employed. The product should be wrapped tightly so as to enclose a minimum amount of air within, and a generous overlap of paper used. If a sealing machine is not available, the wrapper can be held in place by means of rubber bands. The latex bags described for use with whole fish are also very satisfactory for packaging dressed fish.

Shellfish represent a more difficult problem and they can not be expected to keep in good condition for as long as the other fishery products. Shellfish should be removed from the shell, cleaned, and packed in a weak brine solution (about 2 per cent). In the case of crabs, only the picked, cooked meat should be stored. Ordinary waxed cardboard cartons such as are used for ice cream are unsatisfactory for storing shellfish. Much better results are obtained by using glass jars provided with a tight lid. The products should be covered with the dilute brine solution and a small air space provided to allow for expansion during freezing. If this air space is provided, no difficulty with jars breaking during freezing will occur, and the use of air-tight jars

greatly minimizes discoloration and the development of "off" flavors. A waxed cardboard carton with an inner lining of moisture- and vapor-proof paper is also available which should prove satisfactory.

Some locker owners do not like to handle fish in their plants because they believe it results in fish odors being absorbed by other foods. A series of experiments was conducted in which fresh fish were stored with butter in the same locker, and the butter was tested periodically by expert butter graders. No absorption of odor whatever was observed. As long as fresh fish only is frozen, and it is adequately wrapped, no difficulty will be encountered from odor contamination. Absorption of fish odors by other foods signifies that stale fish was frozen. The individual locker proprietor should see to it that only fresh fish are brought into the plant and that they are wrapped in a suitable manner. If this is done not only will he protect other customers, but also those who are storing the fish will obtain a more satisfactory storage of their product.

If full advantage is taken of the opportunity afforded to the fisheries by the refrigerated locker development, a considerable advance will be made toward a more efficient conservation of one of our most important natural resources. Freezing represents one of the best available methods of preserving fishery products against spoilage. The refrigerated locker provides a means of extending this method of preservation to several fields not at present utilizing it, and hence a considerable saving in fish now lost through spoilage may be anticipated.

A NEW FUNGUS DISEASE OF TROUT

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Abstract

A new species of fungus, for which the name *Saprolegnia invaderis* is proposed, was found in fingerling trout at the Leetown (West Virginia) hatchery. Infection occurs through the alimentary tract from which the fungus grows out through the body cavity and the abdominal wall to the exterior, where zoospores and chlamydospores are formed. Growth of the hyphae through the abdominal wall occurs only after the death of the host. A short technical description of the parasite is included.

One of the best known and most widespread diseases of fish is caused by fungus or water molds technically known as Saprolegniaceae. Practically all species of fresh-water fishes appear to be susceptible to such infections under certain conditions. Naturally, however, attention was first directed to the fungus largely as a result of infection of game fishes, especially salmon, which frequently become badly fungused after migrating into fresh water from the sea. As long ago as 1882, T. H. Huxley made an extensive study of fungus associated with a severe epidemic among salmon in British streams. Huxley came to the conclusion that this fungus was a well-known species, *Saprolegnia ferax*, although he admits that since he was not working with pure cultures he had no definite proof of his identification. Nevertheless, from that time until 1923 all *Saprolegnia* found on fish were assumed to belong to this species. However, Coker (1923) in his monograph on the Saprolegniaceae pointed out that the fungus on fish did not produce sexual reproductive bodies and largely for that reason considered it to be a distinct species which he called *Saprolegnia parasitica*. Later, Kanouse (1932) was able for the first time to obtain the sexual organs in *S. parasitica* when grown on certain media and thus confirmed the fact that *S. parasitica* is a legitimate species.

It is the general belief that *S. parasitica* does not attack healthy, uninjured fish, but if a fish is injured mechanically, or by external parasites, or possibly even if its vitality is lowered by unfavorable conditions, infection by fungus may result. Once established, the fungus spreads from the original site of infection by means of root-like hyphal filaments that extend through the skin and may eventually invade the underlying muscles.

Recently, it has become evident that the *Saprolegnia* found on fish show marked differences in many instances, which suggest that the allocation of all fish fungi to a single species may be a too simple solution of the problem. As a matter of fact, it appears probable that several species of *Saprolegnia* may occur on fish.

In January, 1940, a considerable mortality occurred in a small lot of rainbow trout (*Salmo irideus*) fingerlings that had been feeding only a short time. The presence of the infection was called to our attention by Dr. J. S. Gutsell, who noticed fungal hyphae in the intestine of dying fish. Within a few hours after death these fish became covered with a fungus growth that appeared first on the abdomen and spread rapidly over the entire body. This growth was not confined to the surface of the body, as is ordinarily the case, but the hyphae were found to extend through the body wall into the visceral organs.

Further study showed that the infection, instead of appearing first on the surface of the body, actually developed first in the lumen of the stomach and intestine and later grew out through the wall of the digestive tract into the body cavity and eventually to the exterior through the body wall. Growth through the body wall, however, does not occur until after the death of the fish, when its ventral side may become covered with emerging hyphae, as shown in Figure 1, within a few hours. Shortly after emergence of the hyphae, large numbers of zoosporangia and chlamydospores are formed which provide for dissemination of the fungus to healthy fish, but apparently no reproductive bodies are formed within the body of the host.

The appearance of infected fish was quite characteristic. Usually they appeared to have just eaten a hearty meal due to the fact that the stomach and occasionally the intestine was distended with gas. The visceral blood vessels were more prominent and were readily seen through the body wall. In late stages of the disease the lower half of the body between the head and anal fin was much lighter than usual. The light color of this region in contrast with the dark colored dorsal and tail regions gave the fish a striking appearance which evidently is characteristic of the disease and is due to fading of the body color where hyphae are growing through the body wall.

It is probable that in most cases the fungus begins to grow in the lumen of the stomach. Later, the hyphae may extend through the pylorus into the intestine but usually only the anterior end of this organ becomes involved. In one instance, however, the fungus was found only in the posterior end of the intestine with hyphae growing out through the anus. In this fish there was a marked reddish discoloration around the anus that exended anteriorly a short distance. Occasionally the hyphae may grow anteriorly from the stomach into the esophagus and thence out through the gill cavity as well as through the body wall. In one specimen a small mycelium of the fungus was found in the stomach of an apparently healthy fish and had not yet started to penetrate the stomach wall.

As a result of the irritation produced by the fungus, the visceral blood vessels become badly congested and there is a marked accumulation of the blood in infected organs as shown in Figure 2. As the hyphae grow through the stomach and intestinal walls the cells are destroyed and the tissues break down (Figure 3). In late stages the

Figure 1.—Fingerling rainbow trout killed by *Saprolegnia invaderis*, showing hyphae growing out through abdominal wall. (Slightly enlarged)

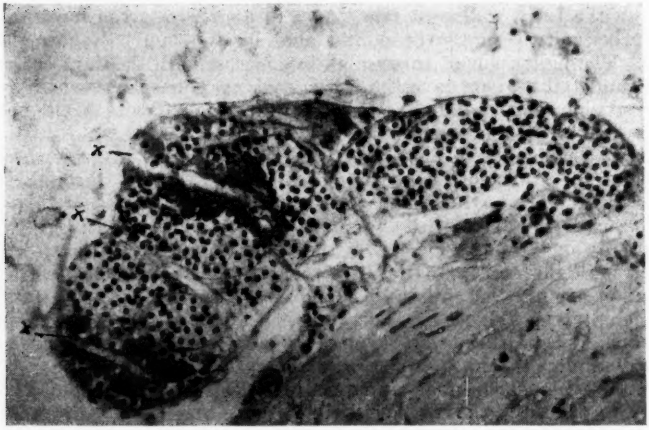

Figure 2.—Hyphae extending through veins gorged with blood. Hyphae are indicated by X. (× 260)

muscular wall of the stomach may be fairly riddled with hyphal filaments (Figure 4). As the hyphae grow, they penetrate any tissue that happens to lie in their course, as in Figure 2, where they can be seen extending through a vein.

Once through the wall of the digestive tract, the hyphae form a network of branched filaments in the body cavity and then penetrate the body wall (Figure 5). As they grow through the body wall there is a marked thickening of the epithelium which is normally only two or three cells thick in this region.

It will be noted that the development of the fungus differs in several important respects from that of *S. parasitica.* Infection takes place through the lumen of the stomach and not through the surface of the body or gills, and, furthermore, it may occur in perfectly healthy fish. When grown on the proper culture media, sexual reproductive bodies are developed which differ in several respects from those of *S. parasitica,* especially in the absence of antheridia which are usually present in that species and in the fact that the oogonia are pitted and not smooth (Figure 6). For these and other reasons it is believed that the fungus is an undescribed species for which we propose the name *Saprolegnia invaderis.* For the sake of completeness a technical description of the fungus follows:

Saprolegnia invaderis: Hyphae well branched when growing in fish or on solid media, less branched in liquid media; ranging from 5 to 13 microns in diameter. Chlamydospores variable; spherical, pyriform, club and cylindrical forms as long as 1.5 millimeters; occurring singly or in chains. Zoosporangia usually cylindrical, zoospores ranging from 9 to 13.5 microns in diameter. Oogonia terminal or on short lateral branches, single, spherical; rarely in chains of two or inter-calary and then only on solid media. Oogonial walls pitted, pits 3 to 5 microns in diameter. Eggs subcentric, ranging from 16 to 26 microns in diameter, averaging 22 microns; 1 to 20 or more in an oogonium. No antheridia have been observed.

This disease was found only in small rainbow trout fingerlings about 1 to 1½ inches long. Whether it may occur in the digestive tract of larger rainbow trout we are unable to say. However, several months after the outbreak described above, the same species of fungus was isolated from a small lesion on the gill of a yearling rainbow trout. The lesion was confined to a few adjacent filaments and was only discovered by accident. There was no evidence that the gill had been injured in any way, and it is possible that this species is capable under certain conditions of directly invading uninjured tissues from the surface. This, however, must remain purely conjectural for the present.

There appears to be no reference to this fungus in the literature with the possible exception of Agersborg (1933) who records a heavy mortality among brook trout (*Salvelinus fontinalis*) fingerlings at a New Hampshire hatchery. According to Agersborg, the small intestine of

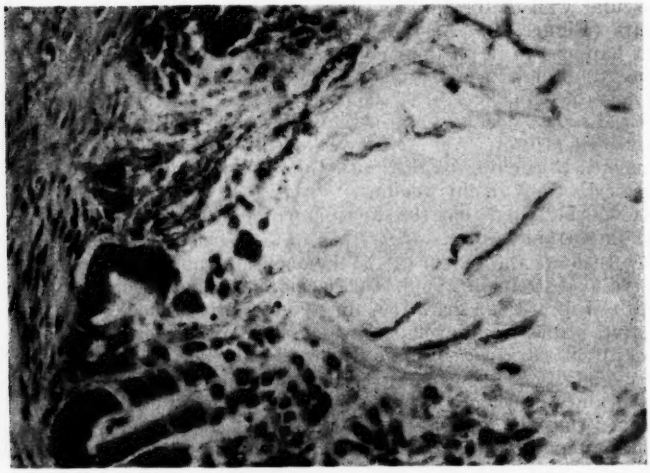

Figure 3.—Fungus hyphae growing through inner lining of stomach causing disintegration of all cells in their path. (× 170)

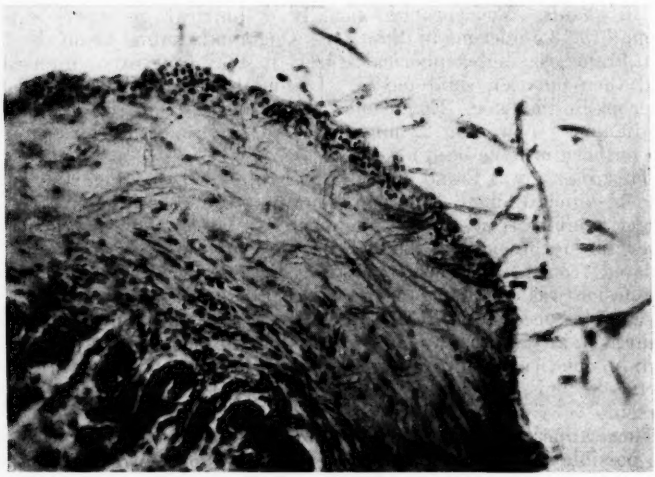

Figure 4.—Muscular wall of stomach with fungus hyphae extending through it in all directions. (× 170)

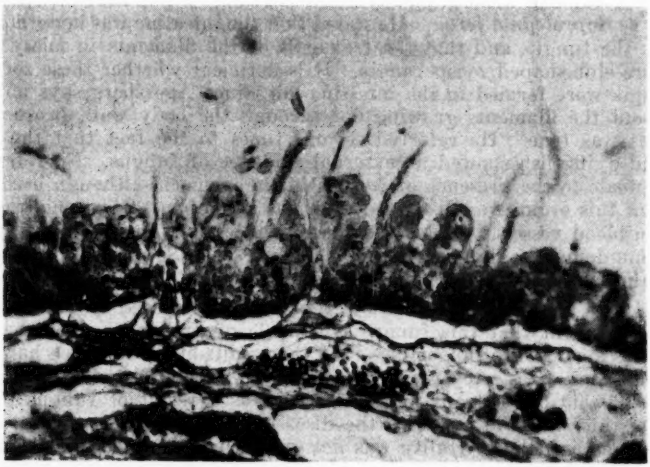

Figure 5.—Hyphae growing out through abdominal wall. Note thickening of the epidermis. The space between the epidermis and underlying connective tissue was caused by treatment of the tissue previous to sectioning. (× 170)

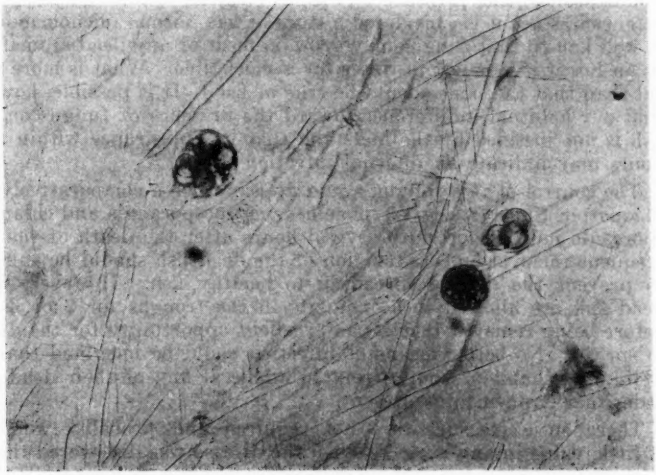

Figure 6.—A pure culture of *S. invaderis* showing structure of oogonia. (× 170)

the dying fish was completely occluded with fungus which he believed to be *Saprolegnia ferax*. He stated that the intestine was honeycombed by the fungus and that the free ends of the filaments in many cases bore club-shaped zoosporangia. It is not clear whether these zoosporangia were formed in the intestine but, since Agersborg says nothing about the filaments growing out through the body wall, presumably this was true. He referred several times to the fact that the dead and dying fish showed no external evidence of fungus. No reference is made to the presence of fungus in the stomach, although he stated that this organ was distended with gas accompanied by congestion of the blood vessels. Under the circumstances it is impossible to determine definitely if Agersborg was dealing with *Saprolegnia invaderis*, although it seems probable that he was.

If the mortality described by Agersborg was caused by *S. invaderis*, it is evident that this fungus is capable of producing much heavier losses among trout fingerlings than the results at the Leetown hatchery would indicate. According to Agersborg, practically all fish in a lot of 400,000 brook trout fingerlings died as a result of fungus in the intestine, while at Leetown the disease was confined to two or three troughs and the mortality was not serious. Unfortunately, the number of fish that succumbed to the disease is not known since it was impossible to determine when the disease first appeared, but, in any case, it was only a small percentage of the fish in the infected troughs.

It appears probable that this species of *Saprolegnia* is widely distributed and may well be the cause of considerable mortality among young trout. The presence of fungus on dead fish would not attract attention, since it is considered a more or less normal phenomenon. It is well known that fungus may grow on meat or any dead animal such as an insect if it is left in water for a short time. What is more natural than that the same should be true of fish? It is possible, however, that our habitual indifference toward the presence of fungus on dead fish is not justified by the facts and that its appearance within a few hours may indicate an internal infection.

The control of this fungus would appear to be a comparatively simple matter. Since external hyphae bearing zoosporangia and chlamydospores do not develop until several hours after the death of the host, frequent removal and destruction of the dead fish should be sufficient to prevent the disease spreading to healthy fish. However, where dead fish are allowed to accumulate in the troughs for 2 or 3 days before being removed there is an excellent opportunity for the disease to spread. No better means of infection could be imagined than the well-known habit of young trout to nibble at any of their dead comrades that happen to be present.

Therapeutic measures are not required and probably would be of little value in any event. When the disease was discovered the fish were divided into two lots of approximately equal numbers, one lot

being given calomel in the same dosage as used for *Octomitus*. The mortality in both lots was approximately the same, and there was no evidence that calomel had any effect on the fungus.

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ETHER ANESTHESIA OF STEELHEAD TROUT[1]

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ABSTRACT

The use of anesthetics offers numerous advantages when handling, marking, or spawning fish which are susceptible to fungus diseases and injuries. Small trout were weighed and measured easily while anesthetized. Steelhead trout, under anesthesia, were very easy to spawn artificially and the loss from eggs so obtained was less than average hatchery losses of eggs for the species. A 1½ per cent aqueous solution of ether anesthetized trout effectively in 45 to 90 seconds and these fish remained relaxed when placed in fresh water for 3 to 20 minutes.

The use of ether and other anesthetics to quiet aquatic vertebrates for experimental purposes is a common practice of biologists and physiologists. The advantages of the use of anesthetics when handling, marking, or spawning fish have not been generally recognized.

During the spring of 1940, it was desired to determine the effect of starvation on the condition factor of a number of 4- to 6-inch steelhead trout, *Salmo gairdnerii,* and cutthroat trout, *Salmo clarkii.* As it was found difficult to determine accurately the standard and total lengths in millimeters of a lively fish flopping on the measuring board, it was decided to try the effect of a 2 per cent aqueous solution of ether in quieting the fish.

Experiments showed that four or five fish could be anesthetized in about 45 seconds by immersion in this solution and when transferred to a pan of fresh water could be measured rapidly and then weighed before they recovered from the anesthesia. No losses occurred in 40 fish so treated and kept for 2 weeks under observation. The temperatur of the hatchery water at the time averaged about 48° F.

Later, it was decided to investigate the effect of lesser concentrations of ether on fish. Five concentrations of ether were used: 0.5, 1.0, 1.5, 2.0, and 5 per cent. The time required to immobilize small steelhead trout when immersed in ether solutions of various concentrations at a temperature of 58° F. is shown in Table 1.

Concentrations of 0.5 per cent and 1.0 per cent were too weak for rapid anesthesia. The 5.0 per cent solution was too severe on the fish for practical use. Little difference was noted between the 1.5 per cent and the 2.0 per cent solutions. A considerable difference was noted in the time required to anesthetize individual fish. (Table 2.) Toward the close of the steelhead trout spawning season the thought occurred to us that anesthesia might be a useful aid in securing the spawn from

[1]Technical Paper No. 354, Oregon Agricultural Experiment Station; published with the approval of the Director.

Table 1.—Time of anesthesia and recovery of small steelhead trout in ether solutions

1940	Group	Number of fish	Percentage concentration	Average size (inches)	Average time of anesthesia (seconds)	Time for recovery (seconds)
June 26	1	4	0.5	5	196	....
June 26	2	4	0.5	4	390	....
June 26	3	4	0.5	2	220	....
Aug. 27	4	2	0.5	5	300	90
June 26	1	4	1.0	5	125	....
June 26	2	4	1.0	2	120	....
Aug. 27	3	4	1.0	6	105	240
Aug. 27	4	4	1.0	4	120	210
June 26	1	3	1.5	6	40	....
June 26	2	4	1.5	2	56	....
June 26	3	3	1.5	4	86	....
June 26	4	3	1.5	6	42	....
Aug. 27	6	4	1.5	4	105	145
Aug. 27	7	1	1.5	9	85	160
Aug. 27	8	2	1.5	7	105	120
Aug. 27	1	3	2.0	4	70	120
Aug. 27	2	1	2.0	9	105	180
Aug. 27	3	5	2.0	5	65	80
Aug. 27	4	2	2.0	8	100	180
Aug. 27	1	4	5.0	9	25	720
Aug. 27	2	1	5.0	3	18	600

these fish. Those who are familiar with the struggling of an 8- or 10-pound steelhead trout during the time it is being spawned will appreciate the obvious advantage of a method which permits these fish to be handled gently. The steelhead trout were removed from the fish trap with a rubber dip net and their tails wrapped with a piece of burlap so that a secure hold could be obtained. The heads were then immersed in a solution containing 200 milliliters of ether in 10 liters of water. The fish struggled very little and apparently the solution caused no discomfort. The extent of anesthesia could be determined by lifting the fish slightly out of the bucket into the light, where it would struggle if conscious. Six steelhead trout, two of them females, were treated with ether. The eggs stripped from females were fertilized with milt from males similarly treated. Stripping of the anesthetized fish was extremely easy as the eggs and milt flowed readily with but the slightest pressure. About 17 ounces of eggs were obtained from each female. All eggs from treated fish were placed in marked baskets for subsequent observation. The aqueous ether solution remained effective on fish throughout a 36-hour period.

The use of cresol for stunning fish recently has been studied by Embody (1940) and it was decided to try a 1:40,000 solution of cresol

Table 2.—Data on the anesthesia of mature steelhead trout with ether

Fish No.	Sex	Time for anesthesia (seconds)	Time for revival
1	female	125	20
2	female	45	....
3	male	60	....
4	male	90	10
5	male	45	3
6	male	45	....

on one steelhead trout. Six and one-half minutes were required for the fish to lose consciousness and about 10 minutes for it to recover after being placed in fresh water. Cresol anesthesia did not cause the fish to relax as did ether. As a result stripping was more difficult and was accompanied by a larger loss of eggs.

After the eggs were placed in baskets, observations indicated the ether-treated fish produced the best eggs. No dead eggs could be detected in this lot and but one broken egg was seen. Seventeen dead eggs were observed in the eggs from the cresol-treated fish. Accurate counts were kept of egg losses until hatching, and the mortality in the eggs from ether-treated fish was 4.2 per cent and from cresol-treated 8.2 per cent. The average mortality from steelhead eggs taken at this hatchery is about 20 per cent, and seldom as low as 15 per cent.

One very noticeable effect of ether anesthesia is to reduce the intensity and amount of handling required to strip the fish. Very frequently losses occur subsequent to spawning brood stock due to internal injury or to fungus on the exterior where the fish have been handled. It is believed that by the use of ether, brood stock losses—due to handling or physical injury—can be reduced materially. Although the number of fish spawned is not sufficient to give an accurate measure of the effect on egg mortality, indications are that losses can be diminished considerably. With large fish, such as steelhead trout, a considerable saving in the time required to spawn a number of fish is affected by the use of anesthesia. Small fish are marked, handled and weighed or measured more easily under anesthesia than when normally active.

Summary

Steelhead trout were easily anesthetized by immersion for 45 to 90 seconds in 1.5 per cent or 2.0 per cent aqueous solutions of ether. Adult fish were very easy to spawn when anesthetized and the resulting eggs showed a lower mortality than those obtained by normal stripping. Small fish were more easily marked, weighed, and measured when under an anesthetic.

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MEASUREMENT OF FISH FOR LIBERATION BY WEIGHING[1]

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ABSTRACT

Accurate measurement of fish produced is essential before the production or efficiency of hatcheries can be compared or evaluated correctly. Where large numbers of fish are liberated, a system of weighing offers an easy and accurate method. Precautions are necessary to assure accurate representative samples of the fish being counted. Large errors occur if seine samples from ponds are depended upon as average samples. Most accurate results are obtained when fish are seined into holding pens and 5- to 10-pound samples of each 100-pound load of fish are counted. Invisible losses occasioned by cannibalism, predators and unseen escapement often are unexpectedly high. Even when a very accurate record is maintained of all observed losses, the number of fish weighed out of the ponds is much less than hatchery records indicate. Conditioning of the fish before hauling is desirable when long truck hauls are necessary. This may be done by not feeding them for 24 to 36 hours. Losses occasioned by overloading or oxygen shortage may not occur until several days after planting. Such losses depend to a large degree on the physiological condition of the fish when they are removed from the hatchery.

INTRODUCTION

The necessity for an accurate weight or count of the fish produced by artificial propagation is generally recognized. Some measure by which the efficiency of different hatcheries can be compared and hatchery methods evaluated is essential. Increasing interest in the number, size, and weight of fish liberated and the results requires exact information regarding the fish planted. Obviously, numbers alone do not mean very much nor do numbers combined with size estimates provide a reliable means of measurement. It has been recognized by a number of the States that production in terms of pounds as well as numbers offers the most accurate means of recording the results of hatchery management and fish liberations. Taft (1933) has described methods of enumerating fish. Deuel, Haskell and Tunison (1937) mentioned the necessity for an adequate sample when making estimates of the number of fish in a pond by the weight method.

There has not been any presentation of the problems of measurement where large numbers of fish are to be liberated from a number of hatcheries having different types and sizes of ponds and producing

[1]Technical Paper No. 364, Oregon Agricultural Experiment Station; published with the approval of the Director.

widely varied sizes of fish. The desirability of having a standard, rapid method giving results of known accuracy for all game fish hatcheries in the State of Oregon resulted in a study of the various methods of fish measurement and the adoption of the method of weighing which is described here.

The object of this paper is to describe and discuss briefly the methods of enumerating fish which are in most common use and the limitations of these methods. The equipment required for weighing, the method of application, and the results obtained are presented. This method provides a system of enumerating the fish with a high degree of accuracy and gives numbers as well as pounds of fish planted.

Methods of Enumeration Commonly Used

Enumeration of fish production begins with the egg count. Despite several descriptions of desirable methods of counting eggs, no well-standardized system is in use today. Some investigators prefer the von Bayer egg rule and chart method by which the number of eggs along a 12-inch line are counted and, referring the count to a table, then gives the number of eggs per ounce or quart. Other investigators have described the use of an egg board which counts 500 eggs at a time and with which the number of eggs in 8 ounces, or 1 quart may be determined quickly. By far the majority of hatchery men count the number of eggs in 1, 2 or even 4 ounces. The number of ounces of eggs in a basket or trough is then multiplied by the average number of eggs per ounce to determine the total number of eggs. There are several possible sources of error in the use of this method and comparisons of counts in Oregon hatcheries show that two men counting a case of eggs rarely obtain comparable results. Accuracy of the egg count is essential as all subsequent calculations of mortality rates refer to the initial figures obtained. The counting of eggs and determination of production figures for fry or fingerlings by subtraction of observed losses is an extremely unreliable and misleading practice and can not be used for final liberation figures if any accuracy is desired.

Yolk-sac fry or No. 1 fingerlings usually are measured by the displacement method. The number which cause a 2- to 4-ounce rise in the water level in a graduate are counted. Enumeration of the fry placed in ponds or tanks is necessary but if the fish are held for any length of time subsequent losses invalidate this enumeration. The same principle of displacement is used frequently in enumerating fingerlings when they are liberated. In comparison with the weight method it is unreliable and does not give an estimate in pounds of the fish so handled.

The enumeration of fish by weighing offers advantages over other methods in that it gives both an estimate of the total number of fish liberated and the actual pounds of fish produced. By determining the number of fish per pound and referring to charts, the average length of any group of fish can be determined.

The so-called "dry" method of weighing in which fish are removed from water in a scaph net or screen bucket and weighed when the water has drained, is obviously detrimental to the fish. A better method is to determine the weight of fish placed in a tub or bucket of water of known weight set on or hung from scales.

The hanging scale used by Taft (1933) has several disadvantages. The accuracy for larger weighings (30-60 pounds) was not as great as with platform scales. When used on a scaffold out of doors, wind caused considerable difficulty. After being used several months, hanging spring scales were discarded in favor of a postal-type platform scale.

Platform Scale in Fish Enumeration and Measurement

The weighing device now in use consists of a lever-action, weight against weight, postal scale. The scale has a capacity of 100 pounds and is small, light (25 pounds), compact, and durable. Since it is graduated in pounds and ounces, its accuracy is such that the addition or subtraction of 3 or 4 fish enumerating 400 to the pound will throw the beam out of balance. The scale is equipped with a locking device whereby the weighing levers can be locked during transportation. Each truck carries a scale to the hatchery from which fish are being distributed.

Square galvanized iron wash tubs having a capacity of about 15 gallons have been found most useful in handling the fish. A tub is placed on the scales and water is added until a balance at 50 or 60 pounds is reached. Five, 10 or 25 pounds of fish are then ladled into the tub until an accurate balance is again reached. Care is necessary in order that a minimum amount of water will be added with the fish. Either rubber or screen ladles are commonly used; rubber dip nets are preferable since they are least likely to injure the fish. When 7 or 8 pounds of fish are in the ladle, a draining time of 5 to 10 seconds is allowed before the fish are poured into the tub. The time allowed for draining should be consistent and unvarying. For the most successful results it is necessary that holding pens having a capacity of 150 to 200 pounds of fish be available to hold weighed loads until the fish trucks can carry the loads from the hatchery. These pens are useful in conditioning the fish by starving for 24 to 36 hours previous to hauling.

A typical operation is as follows. The water in the pond is drawn down and two men seine a load of fish. If 150 pounds of fish are to be carried by the truck, this amount is weighed from the seine into the holding pen. After the fish are in the pen they are crowded to one end and 10 or 25 pounds from the pen are reweighed. These fish are then counted back into the pen and an estimate of the total number of fish in the load is based on this count. Frequently duplicate samples are counted. If the count of 25 pounds is 1,628 fish the count

per pound is 65.12 and the number of fish in the holding pen is then estimated at 8,768.

Results and Discussion

The accuracy of the enumeration depends on a number of factors. The variation in size of fish in the ponds has an important influence on the necessity of counting a portion of each load. Obviously, if the fish in a large pond are all of the same size, or if the sample is truly representative, any weight-count of a seine haul from the pond would give a figure for number per pound, from which the number of fish in the pond could be calculated. As there is an uneven distribution of size of fish in ponds any seine haul not taking the entire number of fish is not a representative sample. This is perhaps best illustrated by Tables 1 and 2 which show the counts obtained as the fish from two ponds were distributed. Referring to Table 1, the probable error of the average count per pound, 32.3, is ± 1.82. Table 1 shows the variation in count per pound occasioned by uneven size distribution of fish in a pond.

Table 1.—Weight counts of loads from hatchery pond No. 12

Load No.	Count per pound (10 lbs. counted)	Pounds per load	Estimated number fish in load	Estimated length (inches)
1	45.9	314	14,412	4.5
2	45.0	314	14,130	4.5
3	38.9	324	12,604	4.7
4	28.1	380	10,678	5.0
5	21.0	300	6,300	5.5
6	34.9	338	11,796	4.2
7	24.3	350	8,505	5.5
8	30.1	330	9,933	5.0
9	26.6	382	10,161	5.0
10	28.4	421	11,956	5.0
Average and total	32.3	3,453	110,475	....

Table 2.—Counts of loads from hatchery Pond No. 1

Load No.	Count per 1 pound		Average count per pound	Pounds in load	Estimated number fish in load
1	311	330	320	100	32,050
2	300	335	317	125	39,688
3	357	311	334	150	50,100
4	329	312	320	125	40,063
5	321	316	318	140	44,590
6	375	353	364	110	40,040
7	361	331	346	18	6,228
8	.....	.....	346	114	39,890
9	332	311 360	334	45	15,211
10	.....	.....	334	79	26,417
11	259	272	265	104	27,612
12	441	.....	441	75	33,075
13	333	.....	333	35	11,655
14	288	.....	288	37	10,556
15	318	.....	318	61	19,398
Average	328		.....	.....	.....
Pounds liberated				1,319	.....
Estimated number liberated					436,573

In Table 2, based on the average number per pound of 328, from 23 counts, the total number of fish liberated would be 433,291, or a difference of 0.76 per cent from the reported figure, 436,573. The probable error ± 5.33 of the mean, 328, indicates that the individual counts for each load are well within normal expected variation. The numbers 436,573 or 433,291 are close to the unknown number actually liberated as indicated by probable error.

The actual difference between the number estimated to be in a load by making a weight-count and the numbers actually in the load as determined by counting every fish was determined in several instances. The results are shown in Table 3.

Table 3.—Comparison of weight-count load estimates with actual load counts

Pounds counted	Number per pound	Pounds in load	Weight by count	Actual count	Percentage variation
....	116.65	100	11,665	11,030	+5.7
20	90.55	70	6,339	6,906	—8.2
20	96.45	70	6,752	6,473	+4.3
15	425.86	60	25,551	25,111	+1.7
10	58.60	100	5,860	6,295	—4.3
20	68.45	100	6,845	6,295	+5.4
50	65.96	100	6,596	6,295	+3.0

The more uniform the length of fish and the larger the sample count, the less the error. On the basis of Table 3 a general numerical accuracy of within 5 per cent is achieved by this method. The poundage liberated is much more definite and basically important. Because of the small amount of water which is carried by each scoopful of fish the poundage production is a little higher by this method, than if a "dry" measure were used. By experiment it was found that in weighing 25 pounds of fish, between 1 ounce and 6 ounces of water were included. On this basis the "dry" weight of a 100-pound load of fish would be between 98.5 and 99.75 pounds.

Fish tolerate handling and hauling very much better if they have not been fed for at least 24 hours previously. This "conditioning" results in a shrinkage in the weight of fish. If the entire pond of fish is conditioned and then weighed out the hatchery man suffers a loss in poundage production. If the fish are weighed into holding pens and then conditioned, the actual poundage carried by the liberating truck is less than that given on the liberating order. Table 4 shows typical weight shrinkage occasioned by conditioning.

Table 4.—Loss in weight occasioned by holding fish 24 hours without food previous to liberation

Holding pen	Weighed and counted (lbs.)	Reweighed and hauled (lbs.)	Number of fish per lb.	Shrinkage (pounds)	Percentage weight loss
A	102.25	93.42	140	8.73	8.5
B	100.00	93.00	126	7.00	7.0
C	127.00	119.06	130	7.92	6.2
D	125.00	116.12	130	8.88	7.1
E	135.00	126.06	119	8.94	6.6
F	145.62	138.62	111	7.00	4.8

Comparative Production

It is obviously unfair to compare two hatcheries as to production solely on the basis of number of fish produced. The equitable method considers size, weight, and numbers as well as losses, cost of operation, rate of growth and other variables. The system of weighing out every fish produced by the 16 game fish hatcheries of Oregon has already produced a general desire for more accuracy in all other hatchery measurements and measurable operations. Fish losses from disease or injury which were formerly frequently estimated are now accurately observed and recorded. Egg shipments are expected to be checked by both the sending and the receiving units. Over-runs after hatching eggs or on measurement of yolk sac fry are definitely not expected and indicate careless egg measurements by the hatchery man. No one expects that a hatchery will be able to liberate the same number of fish as were originally placed in the ponds. The amount of shrinkage varies according to the length of time the fish are held and depends to a large measure on the amount of sickness, predation, escapement and cannibalism which occurs.

Invisible Losses

Our interest has centered on so-called "invisble" losses which in a few instances have amounted to between 40 and 60 per cent of the number of fish on the pond or hatchery inventory. It is of importance to determine what constitutes a normal or expected shrinkage by months for different hatcheries. At present this is not known but the results of several hatchery liberations and checks on shrinkage are of interest and are shown in Table 5.

Table 5.—Hatchery production and shrinkages

Hatchery	Species	Fry-fingerling inventory	Pounds weighed out	Number per pound	Number liberated	Percentage shrinkage
A	Steelhead trout	538,897	1,319.0	330.9	436,563	—18.9
B	Eastern Brook charr	729,232	2,204.0	293.8	657,675	— 9.0
C	Steelhead trout	374,300	2,989.7	136.1	406,987	+ 8.7
	Chinook salmon	32,000	210.3	132.5	27,866	—12.8
D	Chum salmon	106,000	224.2	328.9	84,767	—20.0
	Silver salmon	215,000	513.2	321.6	165,166	—23.1
	Loch Leven trout	989,430	2,179.4	391.0	852,323	—13.9
	Eastern Brook charr	3,506,850	.....	759.0 to [1]172.0	3,830,234	+ 9.2
E	Rainbow trout[2]	131,447	1,610.0	77.6	124,935	— 4.9
	Rainbow trout[2]	173,219	2,195.9	75.2	165,279	— 4.6
	Montana cutthroat trout	658,000	2,614.4	130.0 to 22.0	203,238	—69.0

[1]Variation in number per pound due to growth of fish during liberation season.

[2]These lots were 3 months old when weighed and measured into ponds and 6.5 months old when reweighed and liberated. The shrinkages of 4.9 and 4.6 per cent are the invisible losses during the last 3.5 months.

Physiological Condition

Comparisons of the manner in which loads of fish of known weight withstood or survived transportation have forced attention to differences in the physiological condition of fish intended for liberation. In one instance equal poundages of fish from two hatcheries were transported in milk cans for equal lengths of time and approximately equal distances. Although the temperatures and the losses in oxygen were nearly the same for the two lots of fish, the mortalities differed widely. In another instance a truck was intentionally overloaded (250 pounds) and driven for 5 hours. The dissolved content of the water did not go below 5.40 p.p.m. and averaged about 6.50 p.p.m.

Only a few fish became distressed during the trip and all but 15 fish apparently recovered when returned to a pond. During the next 4 days losses increased and a total of 17.9 per cent or 729 out of the load of 4,125 fish were lost during a 7-day period. Such delayed losses would not have been observed if the fish had been planted.

As a result of these observations we are now paying more attention to the "physiological fitness" of the fish and it is hoped that rapid and easy methods of evaluating this condition may be developed. Care is also taken to avoid overloading of liberation trucks. These two conditions are probably partly responsible for many of the poor results which have been reported from hatchery liberations.

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THE CONDITION OF BROOK TROUT AND RAINBOW TROUT FROM FOUR EASTERN STREAMS

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ABSTRACT

Both native and planted fish of two species of trout were studied to determine the extent of variations in the condition. Brook trout (*Salvelinus fontinalis*) from eastern streams apparently have a lower norm of condition than rainbow trout (*Salmo irideus*). Hatchery fish appear to be handicapped, even when planted in a stream exceptionally rich in food, possibly because hatchery conditions prevent them from developing fully their natural foraging ability. Small streams, although rich in food, are unable to supply the normal food requirements of larger fish. A loss was demonstrated in the condition of adult trout planted in the spring for immediate removal. In the appraisal of streams for stocking, it seems that valuable information may be obtained by an analysis of the condition of the native fish.

INTRODUCTION

The values of the coefficients of condition (frequently termed condition factors) have been used to indicate the suitability or unsuitability of the environment for certain species of fish. When the average coefficient of condition of the fish population is low, further stocking would be harmful if the lack of food is the cause of the poor condition since the continued stocking would result in an even greater reduction in the available food supply for each fish. More attention to indexes of condition of fish would be useful in carrying out stocking programs successfully.

Several investigators have indicated that the coefficients vary within species and populations of fish. Hazzard (1932) noted that brook trout are heaviest at the spawning season, lose weight thereafter, and do not recover their normal relative weight until after several weeks of feeding in the spring. Variations in the value of the coefficient are caused primarily by the state of sexual maturity and the state of nourishment of the fish. Since the data of this investigation are not affected by the state of sexual development, the coefficients may be taken to indicate the degree of well-being or heaviness of fish caused presumably by food conditions in the stream. Measurements of the length and weight of 1,518 brook and rainbow trout were obtained from four streams during the span of the regular fishing season.

The formulas employed for the computation of the coefficient of condition are given below. Both formulas are identical in significance. The one that has been used most generally is:

$$K = \frac{W \times 100}{L^3},$$

where K = coefficient of condition in the metric system,
W = weight in grams,
L = length in centimeters (usually standard length),
and 100 = a factor which places the decimal point near unity.

In the English system, the equivalent formula may be expressed as follows:

$$C.F. = \frac{W \times 100{,}000}{L^3},$$

where $C.F.$ = coefficient of condition in the English system,
W = weight in pounds,
L = length in inches (usually fork or total length),
and 100,000 = factor which places the decimal point usually at the right of two significant figures.

Since previous investigators have calculated coefficients of condition in the metric and in the English system of measurements, a useful conversion factor F has been calculated so that values can be converted readily from one system to the other.

$$F = \frac{453.5924 \times 0.001}{(2.54)^3} = 0.02768$$

where 453.5924 grams = 1 pound,
2.54 centimeters = 1 inch,
and 0.001 = ratio between 100 and 100,000.

Thus, to convert the value of the coefficient from the metric to the English system, divide the metric value by 0.02768; and to convert the value from the English to the metric system, multiply the English value by 0.02768.

The metric and the English formulas for calculating the coefficients of condition of fish have been used with various length measurements, that is, the standard, the fork, and the total length measurements. Hence, the results obtained cannot be made uniform for comparison in all instances because conversion tables or graphs for the three lengths have not been determined even for the common species of fish. Figure 1 offers a convenient comparison of the three lengths of rainbow trout. This graph is based on standard, fork, and total length measurements from large numbers of specimens. Conversions may be made both in the metric and in the English systems.

Table 1 illustrates the need for the standardization of fish measurements and calculations of coefficients of conditions. Six coefficients of condition have been calculated from measurements obtained from a single rainbow trout. It is noted that in the English system the co-

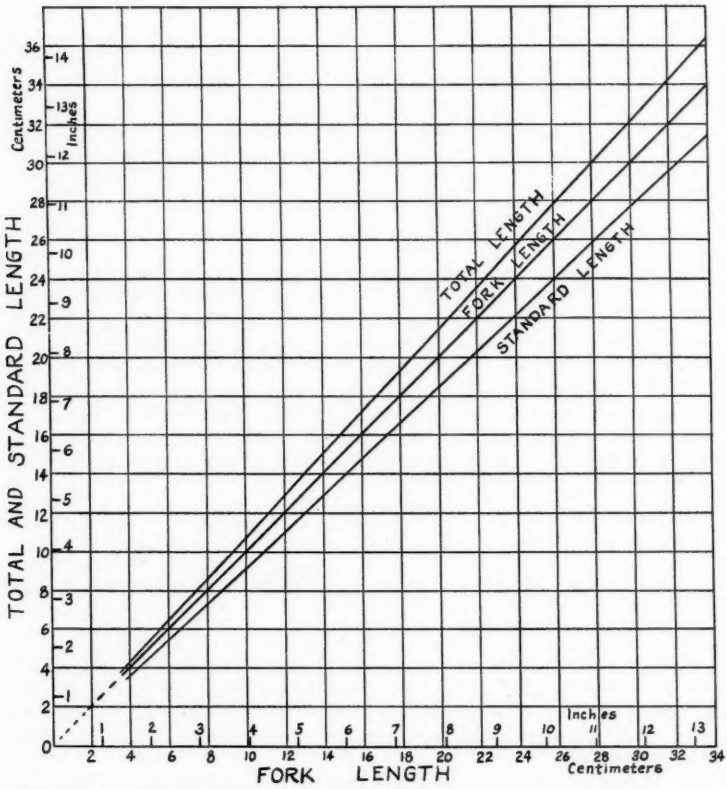

Figure 1.—Relationship between the standard, the fork, and the total lengths of rainbow trout. Conversions may be made both in the metric and the English systems of measurement.

efficients are 56.86, 45.52, and 38.55 for the standard, the fork, and the total lengths, respectively; while in the metric system the coefficients are 1.574, 1.260, and 1.067 for the standard, the fork, and the total lengths, respectively.

Condition of Rainbow Trout from Big Spring Creek

From 1933 to 1940, inclusive, 708 rainbow trout that averaged approximately 10 inches in length were removed from the 1-mile test section of Big Spring Creek located near Leesburg, Virginia. This

Table 1.—Six coefficients of condition calculated from the measurements of a single rainbow trout whose weight was 0.61 pounds (277 grams)

Length measurement on which computation was based	Length (inches)	Coefficient of condition (English)	Length (centimeters)	Coefficient of condition (metric)
Standard length	10.236	56.86	26.0	1.574
Fork length.....	11.024	45.52	28.0	1.260
Total length.....	11.654	38.55	29.6	1.067

trout population was uniform in appearance, although it consisted of native and planted fish. Trout of both groups were exceptionally highly colored and well proportioned, and were vigorous fighters. The marked trout, planted as fingerlings (4 to 5 inches in length) in the fall, became legal-sized trout (8 to 10 inches in length) by May of the following spring. Surber (1936) found that this phenomenal growth was caused by the abundance of fresh-water shrimp (*Gammarus*) in the riffle areas and the relatively uniform water temperatures throughout the year. According to the classification proposed by Davis (1938), food conditions in this stream are Grade 1, that is, bottom food organisms are exceptionally plentiful (average 5.87 grams per square foot).

Despite the fact that the food grade of this stream was highly satisfactory and the trout grew rapidly, the data of Table 2 show that for each year of the period, 1934-1938, the average coefficient of condition of the planted trout was less than the average for the native trout.

In other words, each year the native trout were relatively heavier for their length than were the planted trout. For example, in 1935, the average coefficient of condition[1] for 57 native trout was 43.42 (1.202), whereas the average coefficient for 67 marked trout was 41.86 (1.159). Again, in 1938, the average coefficient for 28 native trout was 43.95 (1.217), while the average value for 25 marked trout was 39.36 (1.089). Even in 1936 and 1937 when the differences were small, the native trout nevertheless had the higher average coefficients.

Probably the most satisfactory explanation for this phenomenon lies in the assumption that hatchery trout, accustomed to an abundance of food obtained with little effort during their early development, are unable to attain the efficiency of native trout in securing food for themselves. In other words, hatchery fish are handicapped, even when planted as fingerlings in streams exceptionally rich in food, because hatchery conditions prevent them from perfecting their natural foraging ability.

The coefficients of condition of the larger trout, 14 to 19 inches in length, taken from Big Spring Creek during the past 8 years, were calculated separately for comparison with the general population. From observation it appeared that these larger trout, weighing up to

[1]In this investigation the coefficients of condition are calculated in the English system, using weight in pounds and fork length in inches. However, to make the text more informative to investigators who have made calculations in the metric system, the metric equivalents are enclosed in parentheses. All tables give both values of the coefficients.

Table 2.—Average values of the coefficients of condition of rainbow trout from Big Spring Creek, Leesburg, Virginia, 1933-1940

Year	Kind of trout	Number of fish	Average length (inches)	Average weight (pounds)	Average value of *C. E.*	Average value of *K.*
1933	Native	92	10.50	0.527	[1]44.42	1.230
1934	Native	77	9.71	0.435	42.91	1.188
	Hatchery	51	9.66	0.380	40.47	1.120
	Both	128	9.69	0.407	[2]41.99	1.162
1935	Native	57	10.50	0.535	43.42	1.202
	Hatchery	67	9.82	0.406	41.86	1.159
	Both	124	10.13	0.465	[2]42.58	1.179
1936	Native	68	10.91	0.576	42.29	1.171
	Hatchery	41	10.00	0.438	41.53	1.150
	Both	109	10.57	0.523	42.00	1.163
1937	Native	37	10.28	0.494	42.55	1.178
	Hatchery	35	9.89	0.428	42.14	1.166
	Both	72	10.09	0.430	42.35	1.172
1938	Native	28	10.20	0.476	43.95	1.217
	Hatchery	25	10.55	0.467	39.36	1.089
	Both	53	10.37	0.472	41.79	1.157
1939	Native	103	8.71	0.322	43.23	1.197
1940	Native	27	10.03	0.468	44.98	1.245

[1]Calculated by Surber (1933).
[2]Calculated by Surber (1936).

2 pounds, were in exceedingly good condition. In reality, however, their average coefficient of 35.28 (0.977) was considerably below the average value of 42.45 (1.175). Since every large trout was below the average condition value for the stream as indicated in Table 3, it seems

Table 3.—Coefficients of condition of rainbow trout 14 to 19 inches in length taken from Big Spring Creek, Leesburg, Virginia, 1933-1938

Year	Month	Fork length (inches)	Weight (pounds)	Value of *C. E.*	Value of *K.*	Kind of trout
1933	June	15.50	1.265	33.97	0.940	Native
1935	July	14.25	1.056	36.49	1.004	Marked
	August	14.00	1.095	39.91	1.105	Native
	"	14.00	0.903	32.91	0.911	Marked
1936	May	17.00	1.423	28.96	0.802	Native
	"	16.75	1.536	32.69	0.905	"
	"	19.00	2.055	29.96	0.829	"
	"	15.25	1.240	34.96	0.968	"
	"	14.50	1.203	39.46	1.092	"
	"	16.00	1.270	31.01	0.858	"
	"	14.75	1.195	37.24	1.031	"
	"	15.50	1.166	31.31	0.867	Marked
	"	16.13	1.303	31.08	0.860	Native
	"	15.13	1.223	35.35	0.978	Marked
	"	14.50	1.250	41.00	1.135	Native
	August	17.81	1.988	35.17	0.974	"
1937	July	15.63	1.485	41.45	1.147	Native
1938	June	14.50	1.287	42.23	1.169	Native
	"	14.00	0.966	35.23	0.975	Marked
Averages		15.48	1.311	[1]35.28	0.977	.....

[1]The average value of the coefficient of condition for the general trout population was 42.45 (1.175).

probable that small streams, although rich in food may be unable to supply the normal requirements of larger fish.

It is well known that occasionally a single trout may take possession of a desirable pool in a stream where it may sustain itself as a cannibal and attain a high coefficient of condition. However, the poor condition of the larger fish substantiates the findings from stomach analyses made by Surber (1936) that no definite cannibalistic tendencies existed in this stream.

Condition of Rainbow Trout and Brook Trout from North Creek

The coefficients of condition of trout from North Creek, located in the Jefferson National Forest near Arcadia, Virginia, were calculated to measure the change in condition of legal-sized trout planted in the spring and removed later during the fishing season. Table 4 contains the data for native and planted brook trout and rainbow trout. It is to be noted that the average condition of one lot of rainbow trout planted 2 weeks before the opening day of the fishing season was reduced from 39.39 (1.090) to 37.93 (1.050) during the 11-week fishing period. Another lot of semi-wild rainbow trout transferred to the stream from a reservoir 5 weeks earlier, suffered a decrease in average condition fom 42.72 (1.182) to 38.58 (1.068) during the same period. The third lot of rainbow trout planted at the same time decreased in average condition from 38.39 (1.060) to 37.22 (1.030).

While there was a decrease in the relative weight of the planted trout, the native rainbow trout maintained their condition during the same period. They averaged 41.38 (1.145) during the early part and 41.40 (1.146) during the latter part of the 11-week fishing period (latter value not listed in table).

Table 4.—Average values of the coefficients of condition of rainbow trout and brook trout from North Creek, Arcadia, Virginia, 1940

Kind of trout	Date stocked (1940)	Date taken (1940)	Number of fish	Average length (inches)	Average weight (pounds)	Average values of *C. E.*	Average values of *K.*
Rainbow trout							
Hatchery	April 5	April 20-22	25	8.89	0.277	39.39	1.090
		June 4-18	25	8.93	0.274	37.93	1.050
Semi-native	February 26	April 20-22	25	9.23	0.334	42.72	1.182
		May 4-June 8	25	9.64	0.359	38.58	1.068
Hatchery	February 26	April 20-22	25	8.68	0.252	38.39	1.063
		May 11-June 5	25	8.58	0.237	37.22	1.030
Native	.....	April 5-May 1	95	6.58	0.126	41.38	1.145
Brook trout							
Hatchery	April 8	April 20	25	7.82	0.169	36.05	0.998
		May 10-June 28	25	7.74	0.168	35.47	0.982
Hatchery	February 29	April 20	25	7.61	0.158	35.88	0.993
		May 3-June 21	25	7.34	0.138	34.76	0.962
Native	.....	April 20-June 13	96	5.89	0.093	37.55	1.039

The data for brook trout from North Creek, also presented in Table 4, substantiate in a general way the data presented for rainbow trout, although the losses in condition were rather small. The two lots of planted brook trout declined in condition from 36.05 (0.998) to 35.47 (0.982) and from 35.88 (0.993) to 34.76 (0.962), respectively, while the native trout maintained their condition at 37.55 (1.039) during the fishing season.

Condition of Rainbow Trout and Brook Trout from Streams of the George Washington National Forest

The coefficients of condition of rainbow trout and brook trout were determined also for collections from two streams located in the George Washington National Forest, Augusta County, Virginia. The St. Mary River, used for production studies by Surber (1940) is relatively poor in food. A total of 11,107 fingerling rainbow trout and brook trout was planted between 1935 and 1938; 268 were recovered for a percentage of 2.4. Although this stream is considered by many anglers as one of the better streams in this area, data presented in Table 5 indicate that its trout population is considerably below normal in condition. In 1938 the average coefficient of condition of the rainbow trout was 37.66 (1.042),—the condition of the native rainbow trout averaged slightly higher than that of the planted rainbow trout. As a result of the large number of calculations made in this study, it is probable that a coefficient of condition of 42.00 (1.163) represents a normal for rainbow trout. In the St. Mary River where the coefficient for the rainbow trout was only 37.66 (1.042) condition seems to have been below normal.

In the same stream, the average coefficient of condition of the brook trout was 35.93 (0.994). Similarly, the planted brook trout were slightly lower in condition than the native brook trout. Compared with the proposed normal coefficient of condition of 40.00 (1.107) for brook trout, these trout also were below normal.

Data obtained from Kennedy Creek, also located in the George Washington National Forest, show that the coefficients of condition of the native brook trout averaged only 34.45 (0.954). The poor condi-

Table 5.—Average values of the coefficients of condition of rainbow and brook trout from George Washington National Forest streams, 1938

Stream	Description of trout		Number of fish	Average length (inches)	Average weight (pounds)	Value of *C. E.*	Value of *K.*
St. Mary River	Rainbow:	native	49	8.42	0.231	37.90	1.049
		hatchery	50	8.04	0.199	37.42	1.036
		both	99	8.26	0.217	37.66	1.042
St. Mary River	Brook:	native	43	7.75	0.175	36.09	0.999
		hatchery	18	7.54	0.158	35.56	0.984
		both	111	7.72	0.171	35.93	0.994
Kennedy Creek	Brook:	native	47	7.44	0.143	34.45	0.954

tion of fish in this stream (average width 5 feet, or only about half the average width of St. Mary River) may be caused by the wide fluctuation in its volume of water. During periods of low water level the foraging range of the trout is restricted to small pools where the food supply soon may become exhausted. This inadequate food situation is reflected in the poor condition of the trout.

Summary

Evidence has been presented that hatchery trout (planted as fingerlings and examined later as adults) were not so well adapted to the food situation in the stream environment as were the native trout. This difference in the ability to forage for food was demonstrated by a comparison of the average coefficients of condition of the marked trout with the native trout from the same stream. It was demonstrated further that adult hatchery trout planted for immediate removal suffered a loss of condition during the fishing season.

Two suggestions present themselves as a result of this study: First, since the condition of the native fish population appears to depend on the amount of food available, the average values of their coefficients of condition at any particular period of the year may indicate the abundance of food in a stream; secondly, it seems that for the successful management of our waters, information about the condition of fish is equally as important as the information about their sizes and numbers.

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THE EFFECT OF TEMPERATURE ON THE WEIGHT OF FASTING RAINBOW TROUT FINGERLINGS

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ABSTRACT

The study was designed to determine at what rate rainbow trout (*Salmo gairdnerii*) fingerlings lose weight at different temperatures under conditions of starvation. The data show that the average percentage loss per day was about 0.9 per cent at 7.94° C., 1.1 per cent at 11.3° C. and 1.3 per cent at 14.6° C. The rate of loss at each temperature is significantly different from the rates at the other temperatures.

INTRODUCTION

Because fish are cold-blooded vertebrates, the effect of temperature on their metabolism has been the object of scientific interest for a number of years. However, it is only within the last 30 years that attempts have been made to measure the relationship accurately. The effect of temperature on metabolism has been studied by a number of workers including Titcomb (1920), Hathaway (1927), Gray (1928), Haempel (1928), Markus (1932), M'Gonigle (1932), and Embody (1934). These studies were restricted to the processes of growth and maintenance and did not consider the effect of fasting.

Atkins (1906) showed that fasting for as long as 20 days did not permanently stunt trout fry. Morgulis (1918) reported on the fat and protein catabolism of brook trout (*Salvelinus fontinalis*) during starvation. Titcomb and others (1928) presented a chart showing a gradual loss of weight for a group of fasting brook trout over a period of 28 weeks. Pentelow (1939) stated that the loss in weight in brown trout (*Salmo fario*) is considerably greater at a temperature between 55° and 60° F. than it is below 50° F.

The only consideration given to temperature in any of these investigations, except Pentelow's, was the attempt to keep it constant in order to eliminate it as a source of variation. On the other hand, for the purpose of metabolism studies, it seemed important to determine the effect of different temperatures on the loss of weight during fasting.

In the New York State trout hatcheries it is customary to determine the number of fish in a shipment on the basis of weight. It is also a routine procedure to starve these fish for about 2 days before shipping. It is, therefore, important to find out just what effect a period of fasting might have on these determinations.

The particular problem then was to determine at what rate rainbow trout fingerlings lose weight at different temperatures under conditions of starvation. Judging from the conclusion presented by Pentelow, it may be assumed that the rate at which rainbow trout fingerlings lose weight varies with the temperature, and, within the range tolerated by rainbow trout, the loss of weight is directly related to the temperature; in other words, the higher the temperature the greater the loss for the same length of time. This hypothesis may be tested by measuring the rate of loss at each temperature followed by a critical comparison of the rates.

Since it is necessary to measure the effect of temperature, the first step is to set up environments in which the temperature conditions are significantly different. The initial size of the fish should also be established by measurement. Mortality, another important factor, should also be considered.

The next step is to set up a criterion for judging the differences in rates. In this experiment, which involves in addition to the independent variable, temperature, two related variables, time and weight, the methods of regression offer a suitable means of handling the data. The regression coefficient, which is the change in weight per gram per unit change in time, provides a common term for comparison of rates. The following experiment is designed to test the hypothesis by this method.

Materials and Methods

Facilities at the Cornell University Experimental Hatchery made possible the use of water at three different temperatures, which can be designated for descriptive purposes as low, medium, and high. The temperature range covers that normally encountered in New York trout hatcheries. A constant temperature apparatus would have been more satisfactory, but in its absence, pumps were used to maintain the temperature as nearly constant as possible. Pumps supplied creek water which had been warmed by recirculation at room temperature. The mean temperatures for the period of the experiment, April 5 through May 5, was calculated from readings taken daily at 8:00 a.m. and 4:00 p.m. with a clinical thermometer calibrated to 0.1° C. Creek water with a mean temperature of 7.94° C. $\pm$ 0.588 (46.3° F.) was used for the low temperature. The creek water was recirculated at two different rates by means of pumps which maintained the water at mean temperatures of 11.3° C. $\pm$ 0.324 (52.3 ° F.), and 14.6° C. $\pm$ 0.266 (58.3° F.), thus providing the medium and high temperatures, respectively. Critical tests of significance by Student's t-test (Fisher, 1936) reveal that the means of the low, medium, and high temperature given above are significantly different in each instance.

A lot of 50 rainbow trout fingerlings, *Salmo gairdnerii* Richardson, was starved at each of the three temperatures. Each lot was placed in a covered wire basket in a separate trough that contained no other

fish. The length of the 150 fish was measured at the beginning of the experiment to establish the initial size. The mean standard length of Lot A at 7.94° C. was 4.20 centimeters ± 0.371; of Lot B at 11.3° C. was 4.16 ± 0.0250, and of Lot C at 14.6° C. was 4.22 ± 0.0248. Student's t-test reveals that there is not a significant difference in length.

Each lot of fish was weighed every day at the same time. The following method of weighing was adopted because of its efficiency. The fish were poured from the wire basket into a net partly submerged in water. The net was lifted out of water and allowed to drain for a period from 3 to 5 seconds. The fish and net were blotted with cheese cloth until no drops of water were visible. Then the fish were emptied into a pan of water balanced on a set of torsion balance scales and weighed. The fish were returned to the wire basket immediately after being weighed. The manipulative error of this method, as determined by weighing two lots of fish nine times each, was less than 1 per cent. The error is so small that it is of little consequence.

Results and Conclusions

The original records are available at the Laboratory of Limnology and Fisheries, Cornell University. The transformed data are presented here. The mean daily weights of the fish at each temperature,

Table 1. Mean daily weights of fasting rainbow trout fingerlings at the three temperatures adjusted to 100 grams to provide comparable initial weights

Days	Lot A at 7.94° C.	Lot B at 11.3° C.	Lot C at 14.6° C.
0	100 grams	100 grams	100 grams
1	99.18	98.60	99.39
2	97.72	94.85	94.03
3	96.88	92.51	91.03
4	94.38	89.70	86.54
5	95.21	91.57	90.18
6	94.59	90.17	89.42
7	95.21	88.53	87.29
8	95.42	88.76	87.29
9	93.12	87.36	85.47
10	92.29	86.19	83.11
11	91.87	84.08	81.61
12	91.25	84.43	80.32
13	90.62	82.67	79.04
14	88.32	82.44	77.75
15	89.16	81.27	77.33
16	88.11	80.45	75.18
17	86.23	77.75	73.04
18	85.61	78.22	72.83
19	84.36	76.11	72.51
20	83.31	76.23	70.26
21	81.01	74.48	69.61
22	78.72	73.66	68.87
23	77.26	73.07	68.44
24	76.84	.....	.....
25	77.05	.....	.....
26	76.42	.....	.....
27	75.59	.....	.....
28	75.17	.....	.....
29	73.71	.....	.....
30	72.45	.....	.....
31	71.62	.....	.....
32	68.38	.....	.....

calculated from the total weight are presented in Table 1, where they have been adjusted to 100 grams to provide comparable initial weights. These values were plotted with the logarithm of the weight on the ordinate and the time in days on the abscissa. It was evident from the graph that the rate of loss was uniform and the best estimate of the rate could be obtained from the equation:

$$b = \frac{\Sigma yt - \Sigma t.\bar{y}}{\Sigma t^2 - \frac{(\Sigma t)^2}{n}}$$

in which: b = change in weight per gram per unit change in time (day), the regression coefficient,
y = logarithm of the weight,
t = time in days,
and n = number of measurements.

The best fitting straight line for each temperature was calculated from the equation: $Y = a + bt$, in which the symbols have the same meaning as above. These lines are shown plotted in Figure 1. The regression coefficient for Lots A, B, and C are: — 0.0111 ± 0.000353; — 0.0127 ± 0.000347; and —0.0160 ± 0.000494 grams per gram per day, respectively.

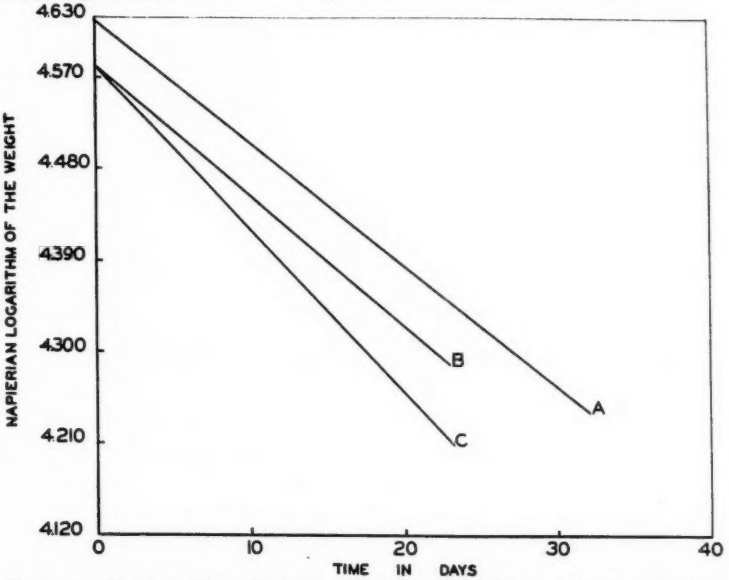

Figure 1.—The best fitting lines for the mean daily weights of fasting rainbow trout fingerlings at three temperatures.

An analysis of the significance of the regression coefficients by Student's t-test shows that with regard to the smallest difference, namely that between Lots A and B, 0.0016 ± 0.000495, the odds are greater than 99:1 that such a difference is due to chance alone. Since the difference between Lots A and C, and B and C are still greater, the rates at which the three lots lost weight are significantly different.

The interpretation of the results may be clarified by Figure 2. This graph shows the loss in weight of 1,000 grams of fish at the three temperatures, calculated from the regression values. These curves present the best estimate because all points have contributed their weight to the determination of a single point. The equivalent weights in the English system are given on the right hand side to facilitate transformation.

Comparison of the data reveals that the loss over a period of 23 days was approximately 30 per cent of the original weight at the high temperature, 25 per cent at the medium temperature, and 22 per cent at the low temperature. As indicated above these losses are significantly different. The average percentage loss of weight per day was as follows: Lot A, 0.9 per cent; Lot B, 1.1 per cent; and Lot C, 1.3 per cent.

The length of the experiment was limited to 23 days by the exces-

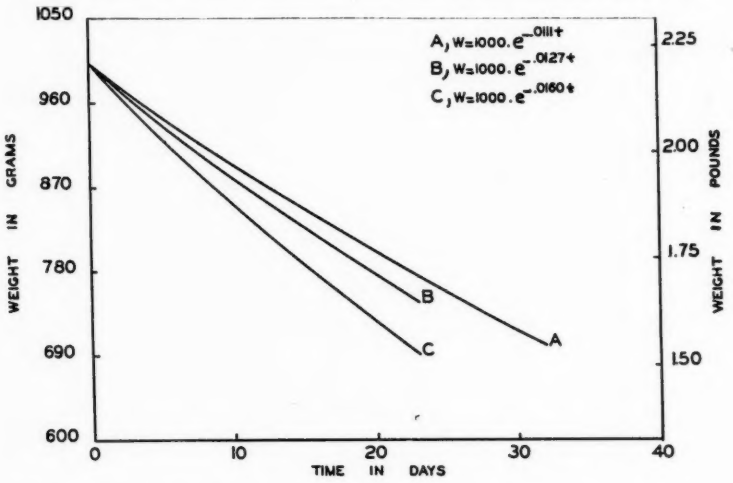

Figure 2.—Loss of weight of 1,000 grams of rainbow trout fingerlings at each temperature calculated from the regression values. Lot A at 7.9° C., B at 11.3° C., and C at 14.6° C. Metric equivalents are shown on the left, English, on the right. In the equations: W = weight in grams; e = 2.7182818 . . . ., the base of Napierian logarithms, and t = time in days.

sive mortality which set in at the end of this period in Lots B and C. There were 50 fish remaining in Lot A, 27 in Lot B, and 32 in Lot C at the end of 23 days. At the end of 32 days, there were 49 fish in Lot A, 14 in Lot B, and 8 in Lot C. It is not possible to predict from this data the length of time fish will endure starvation because of the unavoidable injury incurred from daily handling. The data indicate that fish will live longer under conditions of starvation at lower temperatures.

Judging from the data presented, temperature does affect the rate of loss of weight in rainbow trout fingerlings during starvation. The average loss was about 0.9 per cent per day at 8° C., and 1.1 per cent per day at 11° C., and 1.3 per cent per day at 15° C. Where rainbow trout fingerlings are starved for a day or two before shipment the loss of weight probably is not great enough to affect the calculation of the number of fish from the weight. A more precise determination of the rate of loss for metabolism studies would probably require more sensitive apparatus such as a constant temperature set-up but the above findings undoubtedly will be valuable in designing such experiments.

Acknowledgments

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ACUTE CATARRHAL ENTERITIS OF SALMONID FINGERLINGS[1]

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ABSTRACT

For many years, a disease especially of the Eastern speckled trout, *Salvelinus fontinalis*, variously described as "whirling sickness" or "octomitiasis" has been experienced in almost all trout-rearing establishments. Due to a relative freedom from the parasitic infection, *Octomitus salmonis*, in the hatcheries of the Maritime Provinces, it has been possible to determine the importance of "enteritis" as a factor in the heavy mortalities of the young salmonid fishes in hatcheries. This interpretation explains several of the anomalies previously reported in "whirling sickness." The most characteristic phenomenon of this disease is the large quantity of clear mucus (not stained by bile) present in the upper gut. In the Maritime hatcheries, such fish as have been found harboring *Octomitus salmonis* have been healthy.

INTRODUCTION

Moore (1923) described a disease which affected all species of trout fingerlings that had been examined. This was called "whirling sickness," "gill trouble," or "octomitiasis." Davis (1937), as well as in other publications, has given additional descriptions of the disease.

In numerous investigations in the various hatcheries of the Maritime Provinces of Canada, during the past 10 years, the writer has had the opportunity of making a great many studies of whirling sickness. As a result, it has become increasingly evident that infestation by *Octomitus salmonis* is not an important factor in whirling sickness, and in fact seems to bear no etiological relationship whatever to this disease at these hatcheries.

The basis for this conclusion is two-fold. First, in the very large number of cases of whirling sickness seen and examined, in no instance has *Octomitus salmonis* been discovered. Secondly, in the three hatcheries in which speckled trout, *Salvelinus fontinalis*, infested with *Octomitus salmonis* have been found, there has been no whirling sickness, and indeed the affected specimens semed even more healthy than those not affected with the parasite.

It may be the more northerly location of the hatcheries under consideration which is responsible for the relative immunity to *Octomitus*, which, however, has occurred at three of these hatcheries having the warmest water supplies. It may be significant that whirling sickness itself is absent from the coldest of the maritime establishments, yet is exceptionally severe in the warmest ones; and is less severe in those with intermediate temperature ranges. Under these circum-

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stances, it has been possible to separate octomitiasis and whirling sickness, and to study both uncomplicated by other conditions.

It is submitted therefore that the condition heretofore known as "whirling sickness," or octomitiasis ought to be called, more correctly, "acute catarrhal enteritis"; that it is an inflammation of the intestine, not necessarily related to infestation, and which is responsible for the acute colic which causes the outstanding clinical symptom of this condition. A description of this disease, as it has been observed in the Maritime hatcheries follows. In all essentials, with the exception of the parasites, the symptoms are the same as described by Moore (1923) and Davis (1937).

Definition and Etiology

Enteritis is an exceedingly acute intestinal affection of very young salmonid fishes, particularly speckled trout, usually attacking fry which have been feeding freely only about 2 or 3 weeks, although fry hatched earlier during the winter, are also attacked at approximately the same period.

Although no definite cause is known, all available evidence seems to point very strongly to food, or feeding or both, as a very important etiological factor or factors. Speckled trout are affected chiefly by the disease, although it has been observed in other species, particularly Atlantic salmon, *Salmo salar*. Enteritis usually occurs about the period of initial feeding, which is also the period of rapid warming of the waters (June). It is less common in spring-fed hatcheries where the water supplies do not experience a rapid and great increase in temperature. It seems to be most severe in hatcheries having a late hatch, followed by rapid and marked warming of the water. All groups of fish, even those under apparently identical conditions are not affected, nor is the mortality the same from year to year. Hofer (1906) suggested altered food-stuffs as a probable cause. Davis (1937, pp. 47-48) stressed unsuitable food and overcrowding as causes. Riddell (1935) demonstrated that important changes occur in beef liver after it is ground, which take place slowly at low temperatures and much more rapidly at high ones. That temperature is an important factor is shown also by the fact that in seasons similar to 1940, characterized by continued prolonged subnormal temperatures, enteritis is relatively less prevalent than in seasons of average or above-normal temperatures.

Pathology

Constantly and characteristically, there is a marked increase in the mucus secretion in the upper gut, and simultaneously a complete stoppage in the flow of bile. Hence the mucus of the upper gut instead of being stained a greenish or brownish yellow is clear—almost

water-white. The epithelial cells from the walls of the gut are markedly increased in the mucus and in many specimens bacteria, sometimes in large numbers are seen. In a large number of individuals no bacteria at all, or very few, can be discovered. Cultures of the contents of affected intestinal tracts have been prepared, but no organisms have been found present constantly enough to suggest any etiological relationship. Approximately 22 different organisms have been identified from the gut mucus of the fish dying of acute catarrhal enteritis. This excess or deficit in bacteria may be found in dying fry in the same trough. External or internal parasites, such as *Chilodon* or *Octomitus,* are not usually present, except apparently as a complicating or secondary infestation, which may obscure or prevent the detection of the more serious enteritis.

Pasko (1936) described a condition which agrees in most details with that found in the Canadian Maritime hatcheries, though he did not record the marked temperature increases reported above—in fact the temperatures reported seem to be remarkably uniform. He was of the opinion that herring added to the diet may have been a favorable factor in control. Since this item was not added until July, at which time this particular disease has ordinarily run its course, the observation seems to lose significance. In the Maritimes, acute catarrhal enteritis reaches its peak normally in the first or second week of June. Nothing but a beef liver diet has been used in the local hatcheries although in one or two instances, attempts to add fresh fish to the diet have been made, employing the alewife or gaspereau, *Pomolobus pseudoharengus.* This has always seemed to be disastrous, aggravating the condition instead of alleviating it.

Symptoms and Diagnosis

The symptoms of this disease are very striking. There is usually very violent whirling and "corkscrewing" of affected individuals—so violent that the fish appear to be writhing with pain. After two or three of these violent contortions, the fish sinks passively to the bottom, breathing very rapidly; several severe convulsive seizures may then follow rapidly, the fish finally dying. It is usually, but not always, carried down to the lower end of the trough. The violent whirling would seem to be due to intestinal irritation and inflammation or colic. Sometimes the whirling may not be so violent as indicated above, and in less acute cases, when "pin-heads" dominate, may scarcely be seen. Seemingly, the largest and finest fry become affected most acutely. No other symptoms have been observed.

This disease lasts for a rather prolonged season. It may appear first about the middle of May, reaching its maximum severity, often in three or four hatcheries simultaneously, about the first week of June, then gradually declines towards the end of June. Losses increase sharply, often to 10 or 20 per cent per week at the height of the

outbreak, and occasionally reach as high as 60 or even 100 per cent.

Prognosis is not good. Generally the best and largest fish are lost first and they seem to suffer in greater proportion so that the average weight after an outbreak of enteritis may be much less than before. It may be that the larger fry have been the greedy ones—again indicating the influence of quantity of food as a cause. In the Canadian hatcheries under consideration, the diet has been, for the most part up to this period of development, beef liver, though in Pasko's case this food comprised only 20 per cent of the formula. The cause may be the manner of feeding, too much at too great intervals, or it may be the kind of food.

As indicated above, the severe whirling of the fish usually occurs 2 or 3 weeks after feeding has begun, and it is most probable that this is the condition existing and this diagnosis ought to be made in the absence of demonstrable parasites or other infection. Such diagnosis would be confirmed by discovering upon examination of the intestinal tract of dead fish the presence of plentiful, clear mucus in the upper part of the tract. Sometimes, there may be no bile-stained mucus in the gut of affected fish at all. In some exceptionally acute cases, the gut may be at least half-filled with normal bile-stained gut contents but there will be always a certain amount of clear mucus at the upper end. Whenever parasites occur, there will be greater uncertainty in making a diagnosis and there is danger that the more serious condition may be overlooked.

This condition is to be distinguished from another disease described by Davis (1937) as enteritis. Hofer (1906) also separated intestinal catarrh from intestinal inflammation or enteritis. The latter condition is characterized by inflammatory secretions and severe inflammation of the gut walls, particularly the lower end. The inflammed conditions are not usually seen in acute catarrhal enteritis, though Hofer suggests that the two conditions are due to the same cause and the different response due to the different ages of the affected animals, the inflammatory kind appearing in older, and the catarrhal type in younger animals.

Treatment

No satisfactory treatment, preventive or otherwise, is known. Insofar as has been determined at present, the disease is not due primarily to either parasites or bacteria, so it would seem advisable to put out affected fish into the brooks or feeder streams where they can get natural food-stuffs, such as insect larvae. This seems to be the best suggestion since so much of the rather scant evidence points directly to food or feeding as the most probable cause of the disease. Unaffected fish from the upper end of the troughs could be so distributed with reasonable hope of successful plantings. Where the disease is very acute, and large numbers are affected at the same time, this step may not be feasible.

Experiments with various foodstuffs, feeding intervals, and quantities of food per feeding will be necessary to determine the method of prevention. Cure by any known medicine or bath seem most unlikely to be of any value in view of the fact that the disease apparently is an acute intestinal upset.

Hofer (1906, p. 203) gives an account of this disorder with his opinion of the cause. Because his observations of more than 30 years ago are still quite representative and since his work is unaccessible to most fish-culturists, the following material is translated from his "Handbuch," pp. 203-206:

> Among the most common diseases in salmonid hatcheries is intestinal catarrh of the fry of the year—those being reared on artificial food. This disease exists everywhere, without exception, in all hatcheries using artificial food, and in many places, on the average, demands as victims 20 to 30 per cent of all fry being reared to yearlings, which in every year amounts to hundreds of thousands of young fish. Manifestly, we are dealing with the same phenomenon here, as in any other artificial nourishment of young animals, just as may also be observed in our own children, namely, that the juvenile gut is extremely irritable to unnatural nourishment and reacts violently.
>
> The symptomatic appearance of intestinal catarrh in feeding fry, unfortunately, has not been studied at all, either pathologically or anatomatically; and the intestinal bacteria of the fry are still entirely unknown. Furthermore, nothing is known as yet of the primary causes of these very important practical disease phenomena.
>
> Externally, intestinal catarrh usually manifests itself according to the food stuff, for example, brain, spleen, liver, fish flesh, flesh meal, fish meal, eggs, curd (casein), etc., which have been taken well and readily for some time. The fry will refuse any more, sometimes gradually, sometimes suddenly; thereupon there is a very rapid decline in condition so that within a week either pin-heads have developed to a greater or less extent, or else at the same time, thousands die. Inflammatory processes in the intestinal canal can easily be shown in histological sections.
>
> Generally fry-feeding should be so carefully managed that for the most part, frequent losses of fry will not be due to the same causes as we have described for intestinal inflammation (enteritis) of the growing fish. The disease may occur naturally and even frequently through careless attendance on the fish, through feeding putrid food remains, over-feeding, spoiled food stuffs, overheated or rancid flesh or fish meals.
>
> Probably the most important cause of disease is that the chemical composition of the usual stuffs used for artificial feeding is unfit for the physiological capacity of the young fish gut, so that digestive disorders such as stomach and intestinal catarrh, diarrhoea, occasionally even obstruction, are the result. Indeed, we already know from higher animals that partially decomposed foods, chemically, can not be endured indefinitely and finally lead to death.
>
> In this connection, there are almost no scientifically established facts about fish. This is unfortunate, particularly since we possess almost no physiological knowledge concerning the normal digestive processes of salmonids, especially fry. Here is a rich, practical and fertile field for future investigation. In the meanwhile, the fish breeder has available results of some experiments to assist him in reducing the risk in artificial feeding fry.
>
> According to analogy with the nutrition of the young of domestic animals and of our own young, thoroughly heat-sterilized foods must be given. Nevertheless, each food stuff which reaches the intestine of the fish has had time

enough in the water to be inoculated with bacteria, perhaps even pathogenic kinds. This is especially true if the foods remain lying on the bottom of the troughs for any length of time, and were eaten only after many hours, or even days.

These diseases will be reduced through a feeding method by which the food tsuffs are incorporated in a firm base which is picked apart by the fish as needed. The same end is attained by feeding the fry in so called nurseries; that is latticed chests (boxes with bars) which are suspended in flowing water so that the excess food will be washed away.

Furthermore, the chemical composition of the food stuffs has been determined as far as possible, and definite food compositions recommended. Nevertheless, these troubles have not led as yet to a definite result. There is at present no artificial food stuff which will be good under all conditions and which will prevent the recurrence of intestinal disease to any large extent. Just as for domestic animals and man, so also among fish fry, natural food is at present the only stuff with which fry may be reared in health and with safety. Unfortunately we are still not in any position to supply large amounts of natural food regularly and with certainty at the right time, which the rapid development of fish culture demands, although already a number of methods are known for the mass-production of natural foods. The problem of sound mass-rearing of fry to yearlings is still unsolved.

Discussion

In the description of octomitiasis, Davis (1937) has given the symtoms and pathological picture presented above, and he states: "The evidence at hand is quite contradictory in some respects . . ." The present interpretation of the pathological processes involved seems to clear away all such contradictions and assists in arriving at a clearer view of the whole condition. It seems likely that southern hatcheries experience a greater incidence of *Octomitus salmonis* than do the more northern ones, for in the Maritime hatcheries, as already stated above, this infestation has been found in only three hatcheries, and only in apparently healthy fish.

Although catarrhal enteritis is very severe, at least in some of the Canadian Maritime hatcheries, there are few references to the disease in the literature. As suggested above, perhaps two diseases are being confused, a parasitic one superimposed on an entirely different one caused by a physiological process. This idea seems to offer the most satisfactory and logical explanation of the difficulties pointed out by Davis. The disease is responsible for the greatest losses in numbers of individual fish. There seems to be a very marked susceptibility at the fingerling stage. Recent unpublished work by Dr. H. I. Battle and students at the University of Western Ontario has shown that at the fingerling stage, the pyloric caeca are forming in the Atlantic salmon. Observations have indicated that the caeca are also forming in the speckled trout at this time. This condition probably accounts for the increased intestinal irritability apparently associated with acute catarrhal enteritis.

A comment is needed on Hofer's observation regarding the use of heat-sterilized foods. Modern research has indicated that it is neces-

sary to use a certain amount of fresh unheated food unless the heating be done in an atmosphere free from oxygen. This precludes use of the method of sterilization suggested but in any event this is not important for bacteria pathogenic to fish are not likely to be transmitted by the usual hatchery foodstuffs.

Conclusions

Acute catarrhal enteritis is an inflammatory condition of the intestine of the fry or fingerlings of various salmonid species, characterized by a tremendous mucus secretion with concurrent stoppage of bile secretion and great distension of the gut, at least in its upper portion. This condition occurs in the Canadian Maritime hatcheries without any apparent parasitic or bacterial infestation or infection and appears to be related to faulty technique in feeding. During cold seasons or in the colder hatcheries, the condition apparently does not develop at all, or only slightly, when all other circumstances appear to be otherwise identical.

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Discussion

Mr. Werner: You spoke of *Octomitus* as not developing in cold water or a cold season, when all the other circumstances would seem to be favorable to its development. Could it be that the fish do not feed so well in the low temperature water?

Dr. M'Gonigle: That is the probable explanation. This season in the Maritimes has been very cold and backward.

Dr. Emmeline Moore: I think Dr. M'Gonigle is right. I have not made any study recently, but looking back upon my previous studies, I felt a doubt about the connection between the whirling disease and *Octomitus*. I had always found *Octomitus* present, but your conclusion I believe ties more closely with the facts and I think the diagnosis is correct.

THE EFFECT OF CRESOL ON BROOK TROUT, *SALVELINUS FONTINALIS*

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ABSTRACT

In order to increase the effectiveness of the cresol method of estimating fish populations, a series of experiments were performed to determine the toxicity of cresol in relation to the size of the fish, the concentration of the cresol, and the temperature of the solution. The mean turn-over time was used as a measure of the toxicity. From the experimental evidence obtained, it was concluded that the toxicity of cresol is approximately the same for brook trout from 8 to 14 centimeters long. The concentration and the temperature are very important factors affecting the toxicity of cresol. The relation can be expressed by this equation:

$$1/t = 0.5356 \log C + 0.005827\ T - 0.1274,$$

where "t" = the mean turn-over time, "C" = the concentration of cresol in per cent by volume times one thousand, and "T" = the temperature, ° C. Cresol, if used carefully, does not visibly injure brook trout.

INTRODUCTION

It has been shown elsewhere (Embody, 1940) that cresol can be used to remove fish from streams. The method consists, essentially, of maintaining a certain concentration of the drug in the water until the fish turn over and become helpless. The fish may then be transferred to fresh water, where they quickly recover. From experimental evidence to be presented later, it appears that the fish undergo the reaction without visible injury. The usefulness of the above method to remove fish from streams is greatly hampered by a lack of precise information with respect to the toxicity of cresol.

The toxicity of certain drugs to fish has been expressed in terms of the length of time that is required for the drug to produce some easily recognizable change in the reactions of the fish. For example, one measure of the toxicity of a drug which has been used, is the time required to kill the fish (Gersdorf, 1930). Another measure has been the time required to render the fish helpless (Embody, G. C., 1937). Since the latter reaction is utilized in removing fish from streams, it will be used in this study.

When a trout comes in contact with cresol it reacts by swimming very violently for a few moments, but it soon weakens and turns "belly-up." The interval of time between the first contact with the cresol and the instant the fish turns "belly-up" is defined as the turn-over time. In the present paper, turn-over time will be used to measure toxicity. Although there is considerable variability in the turn-over time of different fish, it was found by means of a preliminary

investigation that the mean turn-over time of 10 trout can be estimated with a precision sufficient to solve the problems encountered in this study.

The Problem

In the actual use of cresol in streams, there are at least three important factors which should be considered. First, experience with other toxic substances indicated that larger fish are sometimes more resistant to the effects of a chemical than the smaller ones. Therefore, it was concluded that the effect of cresol on fish of different sizes should be tested. Second, it is important to determine the effective concentration to use which will not injure the fish nor waste the material. Third, since temperature is important in many of the chemical interactions of living organisms, it was suspected that it might also play a significant part. The purpose of the present study, therefore, was to determine the effect of the toxicity of cresol on brook trout in relation to the size of the fish, the concentration of the cresol, and the temperature. With the above information it will be possible to exercise greater control over the use of cresol when it is applied to streams.

Possible Solution

The only hypothesis which can be tested exactly is the null hypothesis, which can be stated thus: If a series of interactions is set up in which the turn-over time of groups of 10 brook trout placed under varying conditions of length of fish, concentration of cresol, and temperature, is measured; then correlations will be found between the turn-over time and the length, concentration, and temperature, but the correlations will be no higher than would be expected on a chance basis. If this hypothesis is refuted by the evidence of any of the interactions, then it may be assumed that significant correlations do exist.

The solution to the problem can be arrived at by an experiment based on a standard design for correlation analysis (Snedecor, 1938). If the toxicity of cresol is measured in a number of situations in which the size of the fish, the concentration of the cresol, and the temperature of the solution are varied, data can be obtained which can be transformed by the methods of multiple correlation, to provide a test of the null hypothesis. If the above mentioned factors are important, they will produce changes in the turn-over time which can be recognized as significant by available methods of testing this type of data.

Experimental Methods

The actual experimental procedure was decided upon as follows: 160 fish were to be selected from a population of hatchery brook trout. The fish were to be placed, in groups of 10, in 16 aquaria which contained cresol solutions at different concentrations and tem-

peratures. Records were to be made of the turn-over time and the length of each fish, together with the concentration and the temperature of the solution in which it had been placed. By use of the data obtained it would be possible to determine the importance of the size of the fish, the concentration, and the temperature in relation to the toxicity of cresol.

From a population of 300 tagged yearling brook trout whose lengths (tip of snout to last scale in the lateral line) had been recorded, 160 fish were selected[1] for the experiment. In order to eliminate bias in the selection of the fish, they were thoroughly mixed in a trough and lifted out in a scap net, a few at a time. The 160 fish were divided in the same manner into four groups of 40, each of which was segregated into the troughs containing water of different temperatures.

There were available three hatchery troughs with independent recirculating pumps together with the regular hatchery water supply, which could be used to control the temperature. One group of 40 fish was placed in a trough attached to the regular water supply which was only a fraction of a degree above 0° C. The other three groups were placed in troughs with recirculating water supplies. In order to maintain the temperature, water was allowed to circulate continuously through the trough which was located in a warm room, while a small amount of the hatchery supply was added at a constant rate. In each case the fish were placed in the troughs with the recirculating supply and approximate adjustments were made, after which the system was allowed to remain 24 hours or longer to reach equilibrium and to condition the fish.

At each of the four temperatures, four concentrations of cresol were provided. To accomplish this, four aquaria were each filled with 15 liters of water from the trough in which the fish had been conditioned and were immersed in the same trough to maintain the temperature throughout the experiment. Enough commercial cresol[2] was added to the four separate aquaria of each temperature to obtain concentrations of 1:40,000; 1:30,000; 1:20,000; and 1:10,000 by volume. The cresol was first diluted to a 10 per cent solution by measuring out 10 cubic centimeters of the liquid in a graduate and diluting with water to 100 cubic centimeters. The diluted cresol solution for each aquarium was measured with a graduated pipette. The following amounts were measured: 3.75 cubic centimeters for 1:40,000; 5.0 cubic centimeters for 1:30,000; 7.5 cubic centimeters for 1:20,000; and 15 cubic centimeters for 1:10,000. The completed series, therefore, consisted of 16 aquaria in which four temperatures and four concentrations of cresol were maintained. The combinations were such that for each temperature, all four concentrations were represented.

The operations necessary to interact the fish and the cresol required the services of three men: one man to put the fish into the aquaria

[1]Length measurements were available for only 120 of the 160 fish.
[2]*Liquor cresolis compositus*—U. S. Dispensatory, 21st edition, p. 628.

and to take care of them as they were removed, one man to watch the interaction and remove the trout when he judged they had turned over, and one man to record the data. It should be noted that all of the turn-over times were judged by the same man, and thus differences due to variations in personal judgment were eliminated. The experiments were all conducted in the course of two evenings, 12 the first, and 4 the second. Each experiment was performed separately, proceeding in order from the higher temperatures to the lower.

The experimental data (recorded at the scene of operations) consisted of the following items for each of the 160 fish: tag number, concentration, temperature, turn-over time, and mortality after 36 hours. The temperature was taken at the beginning of each experiment with a tested, clinical thermometer graduated to 0.1° C. The concentration was not checked chemically, but was recorded as measured with the pipette. A stop-watch was started as each group of trout was placed in the solution. The stop-watch was allowed to continue running during the course of each experiment, and the turn-over times recorded from it as the fish were removed. The raw experimental data are presented in Tables 1 to 4.

Results

From a casual observation of the data it appears that there is no correlation between the length of a fish and its turn-over time. To

Table 1.—The turn-over time in minutes, and the length in centimeters of brook trout in cresol solutions of various concentrations at 0.6° C.

Concentrations							
1:40,000		1:30,000		1:20,000		1:10,000	
Time	Length	Time	Length	Time	Length	Time	Length
7.12	8.4	4.42	10.7	3.73	12.9	2.25	10.9
8.43	12.2	4.50	11.8	3.77	10.9	2.33	11.2
8.53	14.4	4.65	11.1	3.78	10.7	2.40	12.0
8.77	14.2	4.80	8.8	3.90	11.9	2.53	13.3
9.17	11.3	4.88	12.5	4.02	11.6	2.65	13.2
9.55	14.4	5.00	8.5	4.02	13.9	2.72	13.1
9.58	11.8	5.08	13.3	4.12	12.7	2.77	11.5
9.80	10.9	5.17	9.7	4.18	10.2	2.90	11.7
10.25	11.8	5.27	12.1	4.18	13.6	3.05	10.5
10.83	13.3	5.65	12.1	4.32	9.6	3.10	12.5

Table 2.—The turn-over time in minutes, and the length in centimeters of brook trout in cresol solutions of various concentrations at 11.2° C.

Concentrations							
1:40,000		1:30,000		1:20,000		1:10,000	
Time	Length	Time	Length	Time	Length	Time	Length
6.18	12.5	3.97	13.2	2.58	11.6	1.70	10.9
6.73	10.6	4.07	13.0	2.68	14.1	1.83	11.0
6.75	13.9	4.15	12.0	2.73	10.0	1.83	13.7
7.03	13.6	4.20	12.6	3.02	12.7	1.97	11.4
7.88	13.7	4.57	9.1	3.10	10.2	1.97	12.0
8.07	12.3	4.62	14.3	3.23	7.7	2.07	12.8
8.15	11.4	4.72	9.0	3.30	11.5	2.07	10.3
8.53	12.2	4.83	11.0	3.52	11.4	2.07	9.3
9.40	9.8	5.85	13.0	3.62	11.8	2.15	13.7
11.35	12.9	6.03	9.6	3.63	14.3	2.27	9.0

Table 3.—The turn-over time in minutes, and the length in centimeters of brook trout in cresol solutions of various concentrations at 14.4° C.

Concentrations							
1:40,000		1:30,000		1:20,000		1:10,000	
Time	Length	Time	Length	Time	Length	Time	Length
4.90	13.3	3.23	14.4	2.55	12.0	1.08	13.6
5.53	10.2	3.45	12.0	2.63	13.9	1.43	13.3
6.45	12.8	3.53	11.3	2.85	10.9	1.43	11.7
6.77	12.0	3.82	11.7	3.12	12.8	1.75	12.6
6.97	11.9	3.97	13.1	3.12	11.9	1.88	8.0
7.32	11.6	4.07	12.7	3.23	11.8	2.00	13.1
7.63	15.2	4.17	13.1	3.30	10.4	2.00	12.6
7.90	11.0	4.17	12.5	3.32	8.4	2.10	13.0
11.48	11.4	4.30	10.2	3.43	12.4	2.10	13.3
15.23	11.1	4.43	13.6	3.43	10.6	2.33	14.4

Table 4.—The turn-over time in minutes of brook trout in cresol solutions of various concentrations at 7.5° C.

Concentrations			
1:40,000	1:30,000	1:20,000	1:10,000
6.01	4.10	3.25	2.08
6.32	4.48	3.55	2.15
6.57	4.65	3.60	2.23
6.95	4.72	3.68	2.32
7.18	4.82	3.73	2.48
7.25	4.92	3.83	2.57
7.65	4.97	3.92	2.62
7.82	5.10	3.98	2.65
8.28	5.10	4.43	2.73
8.52	5.48	4.47	2.78

test this observation the correlation coefficient, r, was estimated (Snedecor, 1938) for each of the twelve experiments in which length measurements were available. In every experiment the correlation coefficient was not significant, and likewise the average coefficient for the twelve experiments, $r = -0.0627$ with 118 degrees of freedom, was not significant. It may be assumed safely, therefore, that, under the conditions of this experiment, the length of trout from 8 to 14 centimeters does not have any correlation with the toxicity of cresol.

To test the correlation of concentration of cresol and temperature with turn-over time correlation coefficients were estimated between functions of these factors. It was found that about the most efficient correlation could be obtained between the logarithm of the concentration (measured in terms of percentage by volume $\times$ 1,000), the actual temperature values, and the reciprocal of the turn-over times. The correlations mentioned above were made with the mean turn-over times of each of the 16 experiments. The correlation coefficient between concentration and mean turn-over time, $r = 0.9430$ with 14 degrees of freedom, indicated that concentration is of extreme importance. The partial correlation coefficient between temperature and mean turn-over time, with the effects of concentration removed, $r = 0.6971$ with 13 degrees of freedom, indicates that temperature, while not as important as concentration, has a highly significant effect on the toxicity of cresol.

The combined effects of concentration and temperature can best be shown by means of equation 1:

$$1/t = 0.5365 \log C + 0.005827\ T - 0.1274 \quad \text{.....(1)}$$

where:

t = mean turn-over time

C = Concentration measured in terms of percentage by volume $\times$ 1,000,

and T = Temperature, ° C.

The above multiple regression equation was fitted to the experimental data of Tables 1 to 4 by the method of least squares (Snedecor, 1938).

When cresol is used to remove fish from streams, it is necessary that specified concentrations be maintained for periods long enough to render helpless approximately all of the population. Values obtained when temperature and concentration values are substituted in Equation 1 represent the mean turn-over time, or the time at which about 50 per cent of the fish are rendered helpless. Consequently, these values would not be satisfactory for use in streams. A new equation must be developed which will show the time necessary to render helpless a high percentage, e.g. 95 per cent, of the population.

The mean turn-over time can be transformed to represent what will be called the 95 per cent turn-over time by adding a value equal to twice the standard deviation of the mean turn-over time. It can be seen from the original data that the range of the turn-over times is greater for the lower temperatures and concentration. The standard deviations for each mean turn-over time, therefore, will not be constant, but will vary proportionately with the mean. The average, within-experiment coefficient of variation was estimated from the logarithms of the turn-over times of Tables 1 to 4 by an analysis of variance. This value was used to calculate the standard deviation of the mean turn-over time.

To obtain a relationship between the 95 per cent turn-over time and the concentration and temperature, Equation 1 has been transformed to Equation 2.

$$1/t' = 0.4461 \log C + 0.004845\ T - 0.1060 \quad \text{.....(2)}$$

where:

t' = The mean turn-over time plus twice its standard deviation,

C = Concentration measured in terms of per cent by volume $\times$ 1,000,

T = Temperature, ° C.

For use in streams, Table 5 has been prepared, showing the 95 per cent turn-over times for various temperatures and concentrations of cresol. It should be remembered that this table represents the 95 per cent turn-over times of hatchery brook trout only, under the conditions described above. It has been used successfully in several central New York streams in the collection of brook and brown trout, but may require modification when used in other streams.

Table 5.—The 95 per cent turn-over time in minutes for various concentrations of cresol and at different temperatures

Temperature ° C.	Concentration				
	1:40,000	1:30,000	1:25,000	1:20,000	1:10,000
2.5	11.95	7.28	5.72	4.58	2.84
7.5	9.23	6.18	5.03	4.14	2.65
12.5	7.55	5.38	4.49	3.75	2.49
17.5	6.40	4.76	4.04	3.44	2.36
22.5	5.53	4.27	3.68	3.17	2.22

Finally, it should be mentioned that the 160 trout were observed for 36 hours after the experiments were performed and no mortality occurred during this time. From this data it was judged that the cresol did not injure the fish.

Conclusions

Here the null hypothesis is stated again: If a series of interactions is set up in which the turn-over time of groups of 10 brook trout placed under varying conditions of length of fish, concentration of cresol, and temperature, is measured; then correlations will be found between the turn-over time and the length, concentration, and temperature, but the correlations will be no higher than would be expected on a chance basis. From the evidence obtained in the experiment, the following assertions seem warranted:

1. In the case of length of fish the null hypothesis is confirmed. The toxicity of cresol is approximately the same for brook trout of different lengths when they are exposed to the same conditions.
2. In the case of concentration of cresol and temperature the null hypothesis is refuted. The concentration and the temperature are very important factors in their relation to the toxicity of cresol.
3. Cresol when used under the conditions of this experiment, does not visibly injure brook trout.

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A QUANTITATIVE STUDY OF THE FOOD OF THE SMALLMOUTH BLACK BASS, *MICROPTERUS DOLOMIEU*, IN THREE EASTERN STREAMS

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ABSTRACT

A study of the food of 308 adult and 1,076 fingerling smallmouth black bass (*Micropterus dolomieu*) from the Shenandoah River, South Branch of the Potomac, and Cacapon Rivers is reported. The adults in the latter two rivers consumed a large number of items insignificant in their size. Fast-growing bass from the Shenandoah River had eaten few but large items, chiefly madtoms (*Schilbeodes insignis*) and various minnows. The viscera of Shenandoah River smallmouth black bass contained large quantities of fat as compared with the relatively small quantities of fat in the viscera of adult fish from the other two rivers. This characteristic of well-fed, fast-growing smallmouth black bass might be used in determining directly food conditions in a stream.

Unlike fry and fingerling smallmouth bass of lakes, the first food of the bass in these rivers consisted mainly of small midge larvae, mayfly nymphs, and occasionally fish.

Analyses of the food of fingerling smallmouth bass are given by seasons, and the food of all bass is correlated with available food supplies studied quantitatively by bottom sampling. In general, the effective food grades for both riffles and pools are low, indicating that quantitative bottom sampling did not measure the food available for the fish with great efficiency. Effective food grades were shown by the bottom samples to be higher in pools than in riffles.

INTRODUCTION

In general, the types of food consumed by smallmouth black bass, *Micropterus dolomieu* Lacépède, are fairly well-known. Practically all the important studies that have been made of the food of fry, fingerlings, or adults have been based on material collected from lakes. The purpose of this study has been to collect information on the types of food eaten in streams and to determine the relative importance of the different items eaten compared to the potential food supply as measured by bottom sampling. The method of Hess (1941) has been used in correlating the results. In none of the important studies hitherto conducted has there been an attempt to correlate directly the actual food consumed with the food determined quantitatively in the environment of the fish. Hubbs and Bailey (1938, p. 54) stated:

> "It is becoming more generally accepted among fisheries investigators that food habits are to a large extent dependent upon the availability of different food organisms. It is invalid to assume, because stomachs contain certain food items, that these items are preferred and that other items have been rejected."

The most important food studies of smallmouth black bass have been made by Tester (1932), Wickliff (1920), Eaton (1928), Moore (1922), and Sibley and Rimsky-Korsakoff (1931). Tester's study was based on an examination of the stomachs of 540 fish of all sizes obtained from various lakes in Ontario. He noted that as the fry increased in length, several changes in diet took place. These changes were correlated with the ability of the growing fish to take organisms of increasing size. In the larger lakes, Georgian Bay (a part of Lake Huron) and Lake Nipissing, the food of the larger bass consisted of about 75 per cent crayfish and 25 per cent fish, mostly yellow perch. In a smaller lake, Perch Lake, fish and crayfish were the most important items, but, in addition, a large percentage of insects and other organisms entered into the diet of the smaller fish. Wickliff (1921) examined 313 specimens from 0.85 to 6.50 centimeters in length from the western end of Lake Erie. He concluded that copepods and cladocerans were the most important food until the fish attained a length of 15 millimeters. From 16 to 45 millimeters copepods and cladocerans, mixed with mayfly nymphs, midge larvae and pupae, fish, and adult insects were important.

The present study is based on the examination of the stomachs of 1,076 fingerling and 308 adult smallmouth black bass. Monthly collections of approximately 100 fingerling smallmouth bass were made during 1936 from the Shenandoah River near Berryville, Virginia, and the South Branch of the Potomac River near Romney, West Virginia. These were collected in the same sections in which bottom-fauna and forage-fish studies have been made. Material for the study of adult food is based on the examination of 308 specimens, 108 of which were collected in the Shenandoah River, 96 in the South Branch of the Potomac, and 104 in the Cacapon River during the period from May 25 to October 27, 1939.

Methods

Collections of bottom organisms by the square-foot method, described in full by Davis (1938), were made at monthly intervals from May to November, in riffles of the test sections (each about 4 miles in length) of the Shenandoah River near Berryville, Virginia, the South Branch of the Potomac River near Romney, West Virginia, and the Cacapon River near Largent, West Virginia. Usually 10 samples were collected on each monthly excursion. A series of samples duplicating those of 1936 was taken in the same riffles. In the Cacapon River only one series of riffle samples was taken. This was collected in 1937 over a 5-month period. In 1937, a series of samples collected with the square-foot bottom sampler was taken in pools in the Shenandoah River and South Branch of the Potomac River in the test section. The purpose of these collections was to afford a background for food studies. In addition to collections of bottom samples and collections of bass, extensive collections of the forage fishes associated with the

bass were made during 1936 and 1937. Details regarding the minnow censuses are not included in this paper. The abundance of forage fish, however, has a very important bearing on the food of the bass, particularly the adults, in these rivers.

Forage minnows are most abundant in the Shenandoah River where, for example, the last minnow census in late August or early September, 1938, showed 124 schools per mile in the Shenandoah, 76 per mile in the South Branch of the Potomac, and 27 per mile in the Cacapon River. The physical and biological characteristics of the three rivers mentioned, which vary considerably, were described in an earlier paper (Surber, 1939). In connection with the abundance of forage fishes in these rivers, it should be noted that the physical characteristics of the Shenandoah River might make those forage fishes present more available. The water edges of the Shenandoah River through most of the season are quite steep, while the shore lines of the South Branch and the Cacapon River have, at least on one side, a shallow, shoaling edge. In the Shenandoah River forage minnows, principally blunt-nosed minnows, *Hyborhynchus notatus,* and straw-colored minnows, *Notropis hudsonius,* find their shelter in the weed beds of the water willow, *Dianthera americana,* while swift and high-swimming attractive minnows, *Notropis amoenus,* and rosy-faced minnows, *Notropis rubellus,* occupy the open water immediately below riffles. In the South Branch and the Cacapon Rivers, weed beds are less extensive, and the forage minnows, chiefly blunt-nosed minnows and small fallfish, *Leucosomus corporalis,* find shelter at the very margin of the water along the shallow edges of gravel bars.

Forage Ratios and Effective Food Grades

In the study of the food of a species of fish, there has been a need for a quantitative method of correlating directly the kinds of food items eaten with the food available in the environment. Effective fish-management programs should be based, in part, upon studies of the interrelationships between feeding habits of a particular species in a stream and the food available. In some streams, for example, the primary food of adult bass might be forage fish, while in another stream, where forage fish are scarce, they might be more dependent upon bottom foods. There are methods for determining the abundance of both forage fishes and bottom animals, but the extent of their value is as yet uncertain. Bottom samples have been taken in a number of recent studies to determine the abundance of bottom animals. The question arises as to their usefulness in determining actual food values for a particular species of fish. Hess (1941) has supplied a method for determining the utility of bottom sampling in the study of the food of fish. The method was tested by him on 90 specimens of the black-nosed dace, *Rhinichthys atratulus.* In this study, 10 bottom samples had an average of 388.0 organisms per square foot. Applying

his method of determining forage ratios and effective food grades, described below, he found that although there were 388.0 organisms per square foot, only 203.7 organisms per square foot were of the kind consumed by the dace to the extent of 1.0 per cent or more of the total number of items. In this study his method has been applied, on a larger scale, to the food of the smallmouth black bass. As was expected, the data accumulated for this species do not indicate as close a relationship to the bottom fauna as Hess found in his study. It should be pointed out that even though bottom sampling may appear to be only 33 per cent effective in the case of one species, such as the smallmouth black bass, it may be much higher in a species of forage fish upon which they are dependent.

Forage ratios for the various sizes of bass studied have been computed. In addition, the effective food grades of riffles and pools have been determined according to the methods suggested by Hess. In this method forage ratios are determined by dividing the percentage of each item found in the stomachs of the fish by the percentage of the same item in the bottom samples. Forage ratios have been calculated for those items of food which make up at least 1 per cent of the total number of food items consumed by each random sample of bass (usually 100 specimens). When the forage ratio for a particular item is 1.0 or more, the abundance of each particular item of food is given its full value in determining the effective food grade. If the ratio is less than 1.0, the available number of bottom organisms of a particular kind is multiplied by this lower ratio to determine its effective food grade. In Table 5, for example, under Cacapon River there are listed the available number of organisms per square foot in the riffles. The average of the total is 147.5. *Baetis* nymphs in this table average 10.76 organisms per square foot and comprise 7.29 per cent of the total average number (147.5). The forage ratio for *Baetis* nymphs is found by dividing 67.33, the percentage of the food made up by *Baetis* nymphs, by 7.29, the percentage of *Baetis* in bottom samples. The forage ratio is 9.24 (greater than 1.0). The food value, 10.76, of *Baetis*[1] nymphs per square foot is carried over to the last column under food grade values.

The forage ratio for *Heptagenia* is 0.49, and being less than 1.0, the average number of *Heptagenia* (20.49) occurring per square foot is multiplied by 0.49, which gives an effective food grade for that particular item of 10.04 in the fifth column of the table. The effective food grade is determined by adding together the values obtained in the fifth column, which, in this case, totals 25.46. The total average number of organisms per square foot in this example is 147.5. There-

[1]The subfamily Baetinae and family Heptageniidae recently have been subdivided (Needham, Traver and Hsu, 1935). The generic name *Baetis* and *Heptagenia* are employed here because they were used thus by Needham and Needham (1930) before the appearance of the new publication (1935). It therefore is possible that the genera *Baetis* and *Heptagenia* used here do not have the same connotation as in the work of Needham, Traver and Hsu, but refer, at least, to closely related genera.

fore, as computed by this method, only 17.26 per cent of the organisms present may be considered available fish food organisms.

The numerical method of analyzing data of this type naturally has its limitations and does not give a true picture of the importance of various items in the diet. For example, in Table 5, which shows the food of Shenandoah River fry of May 13, 9 of the 99 specimens consumed fish. In the numerical analysis, fish constituted only 0.81 per cent, whereas by volume, fish actually made up about 10 per cent of all food. Frequencies and total number of items of food have been shown in these tables to facilitate a complete analysis of the data by the reader. Table 1 gives the volumes of the more important food organisms. Volumes were determined by liquid displacement, except for *Cyclops,* for which the volume was calculated on the basis of individual measurements of several specimens.

Table 1.—Volumes of samples of the important aquatic organisms found in smallmouth black bass stomachs. (Source: Shenandoah River and South Branch of the Potomac River.)

Organism	Number of specimens	Average length (millimeters)	Range in length (millimeters)	Individual volume (millimeters)
Cyclops	....	....	.....	0.102×10^{-4}
Cambarus	3	....	.....	5.667
Baetis nymphs	91	4.22	2.5- 5.0	0.002
Heptagenia nymphs	78	6.15	3.5- 9.0	0.007
Isonychia nymphs	13	10.44	7.5-15.5	0.020
Ephemera nymphs	66	9.27	5.0-20.0	0.012
Potamanthus nymphs	65	10.92	5.5-18.5	0.018
Hexagenia nymphs	18	18.22	13.5-29.0	0.077
Tricorythus nymphs	15	3.49	2.8- 6.0	0.002
Enallagma nymphs	18	13.67	5.5-17.0	0.019
Boyeria nymphs	4	15.00	11.5-20.5	0.070
Ophiogomphus nymphs	3	....	17.0-18.0	0.097
Corydalus larvae	5	44.90	18.5-66.00	1.000
Sialis larvae	23	8.63	5.0-17.00	0.011
Hydropsyche larvae	41	....	.....	0.008
Neureclipsis larvae	3	8.53	7.2- 9.2	0.009
Corixa nymphs	17	3.32	1.7- 4.5	0.004
"Sponson" bugs[1]	10	4.00	.....	0.002
Chironomid larvae	198	6.98	3.0-14.0	0.604×10^{-3}
Eriocera larvae	5	9.24	6.5-10.5	0.011
Tadpoles	2	20.00	16.0-24.0	0.100
Hyborhynchus notatus	8	16.75	15.5-18.00	0.050
Notropis amoenus	30	16.50	.....	0.017
Nitocris	15	4.58	3.0- 6.0	0.017

[1]Unidentified terrestrial Hemiptera nymph.

The data on the actual volumes of the fish-food organisms are given chiefly to enable those interested in this problem from a more theoretical standpoint to convert the numerical data into volumetric data. This conversion may be accomplished by working back through the total number of food items given for the entire random sample of bass in each monthly collection. The tables show the percentage which each kind of organism constitutes of the total number of items. By multiplying the total number of food items by the percentage for each item, one may determine how many organisms of each kind were eaten

by that certain number of smallmouth bass in each collection shown in the frequency column.

As pointed out by Hess and Rainwater (1939), the exoskeletons of crayfish, stoneflies, and mayflies remain undigested for a considerable period of time. However, how long they remain in the stomach under natural conditions will be a difficult matter to determine and is complicated by the size of the meal consumed, water temperatures, and other variable factors.

Adult Food

Examination of the stomach contents of the adult smallmouth black bass, classified from formalin-preserved material according to size and source in Table 2 revealed great differences between those from the Shenandoah and those from the Cacapon and South Branch of the Potomac. The large number of items of food consumed by the bass in the Cacapon River and the South Branch of the Potomac is striking when compared with the much smaller number of food items consumed in the Shenandoah River.

Table 2.—Frequency of various sizes of large or adult smallmouth black bass in a study of their food. (Classified from formalin-preserved material.)

River	Fork lengths in inches					
	4.0-5.9	6.0-7.9	8.0-9.9	10.0-11.9	12.0-15.00	Total
Shenandoah	0	9	26	37	36	108
South Branch of the Potomac	2	24	57	13	0	96
Cacapon	1	37	47	15	4	104

In the Cacapon and South Branch of the Potomac, an average of 12.5 and 22.7 items, respectively, were eaten per fish, while in the Shenandoah the average number of items eaten per fish was only 1.9. The large number of organisms relatively insignificant in volume, such as *Baetis* nymphs and imagoes or sub-imagoes eaten by smallmouth bass in the Cacapon River and South Branch of the Potomac, indicates scarcity of the items upon which bass grow most rapidly, that is, forage fish. These data are presented in Table 3.

The percentage of bass that consumed such important organisms as fish, crayfish and hellgrammites, which may make up a considerable percentage of food by volume, and those which had empty stomachs, are shown in Table 4.

The data for the food of the adult smallmouth bass in these three rivers show a striking difference which can be attributed to variations in the availability of food organisms. In the Cacapon and South Branch of the Potomac Rivers the adults evidently spend a considerable part of their time feeding on insignificant items, while in the Shenandoah the principal food is fish. When the Shenandoah bass are not eating fish, they apparently go without food, as evidenced by the small number of items present in their stomachs.

Item	Cacapon River (104 specimens)			Shenandoah River (108 specimens)			South Branch of Potomac River (96 specimens)		
	Frequency	Total No. of items	Percent'ge of total	Frequency	Total No. of items	Percent'ge of total	Frequency	Total No. of items	Percent'ge of total
Crustacea									
Crayfish (*Cambarus* sp.)	13	14	1.08	9	9	4.31	12	13	0.60
Ephemerida (mayflies)	5	9	0.69	..	..	.....	11	43	1.97
Baetis nymphs	12	202	15.56	4	6	2.87	40	917	42.10
Baetis imagoes	8	672	51.77	..	..	.....	10	877	40.27
Heptagenia nymphs	14	79	6.09	1	1	0.48	20	55	2.53
Heptagenia imagoes	4	10	0.77	..	..	.....	4	6	0.28
Ephemerella nymphs	3	5	0.39	..	..	.....	6	14	0.64
Ephemerella imagoes	1	1	0.08	..	..	.....	1	4	0.18
Isonychia nymphs	11	24	1.85	12	70	33.49	12	46	2.11
Isonychia imagoes	2	2	0.15	..	..	.....	..	..	.....
Ephemera nymphs	1	3	0.23	..	..	.....	..	..	.....
Potamanthus nymphs	..	..	.....	4	4	1.91	11	16	0.73
Hexagenia nymphs	..	..	.....	2	2	0.96	..	..	.....
Odonata									
Damselfly nymphs	2	7	0.54	..	..	.....	1	1	0.05
Damselfly imagoes	28	83	6.39	5	10	4.78	..	..	.....
Dragonfly nymphs	5	10	0.77	3	4	1.91	9	9	0.41
Dragonfly imagoes	3	6	0.46	2	3	1.44	..	..	.....
Plecoptera (stoneflies)									
Acroneuria and *Perla* nymphs	2	2	0.15	2	2	0.96	8	9	0.41
Stoneflies (imagoes)	1	1	0.08	..	..	.....	3	3	0.14
Megaloptera									
Corydalus	..	..	.....	5	5	2.39	6	6	0.28
Trichoptera									
Caddis larvae	1	1	0.08	1	2	0.96	..	..	.....
Hemiptera (water bugs)									
Corixidae (water boatmen)	..	..	.....	1	1	0.48	2	4	0.18
Gerridae (water striders)	11	68	5.24	..	..	.....	..	..	.....
Lepidoptera									
Elophila larvae	..	..	.....	1	1	0.48	..	..	.....
Diptera									
Chironomid larvae	1	1	0.08	1	1	0.48	2	2	0.09
Craneflies (adults)	..	..	.....	..	..	.....	5	8	0.37
Coleoptera	1	1	0.08	..	..	.....	..	..	.....
Gyrinidae adults	1	4	0.31	..	..	.....	..	..	.....
Gyrinidae larvae	2	3	0.23	..	..	.....	..	..	.....
Other aquatic insects	..	..	.....	..	..	.....	1	1	0.05
Terrestrial insects	..	48	3.70	..	9	4.31	..	50	2.30
Mollusca									
Nitocris	1	5	0.39	..	..	.....	2	3	0.14
Amphibians (frogs or toads)	2	2	0.15	1	1	0.48	2	2	0.09
Vertebrates									
Fish									
a. darters	4	5	0.39	8	8	3.83	4	8	0.37
b. minnows *Notropis* sp.	2	2	0.15	30	34	16.27	5	16	0.73
Hyborhynchus	..	..	.....	..	..	.....	3	4	0.18
Leucosomus	1	1	0.08	3	3	1.44	..	..	.....
c. *Schilbeodes*	3	3	0.23	21	23	11.00	3	3	0.14
d. bass	7	7	0.54	4	4	1.91	6	56	2.57
e. sunfish	7	11	0.85	2	3	1.44	..	..	.....
f. rock bass	1	2	0.15	..	..	.....	..	..	.....
g. unidentified	4	4	0.31	3	3	1.44	2	2	0.09
Totals	..	1,298	100.01	..	209	100.02	..	2,178	100.00

Table 4.—Percentages of adult smallmouth black bass empty stomachs and stomachs containing volumetrically important foods

River	Percentage of empty stomachs	Percentages of Stomachs containing:		
		Fish	Crayfish	Hellgrammites
Cacapon	13.5	26.0	12.5	1.0
South Branch of Potomac	14.6	20.8	12.5	4.3
Shenandoah	20.8	56.6	8.5	4.7

Table 3 also brings out differences in the apparent availability of certain forage fishes. For example, 21 of the Shenandoah River smallmouth bass had consumed mad-toms (*Schilbeodes insignis*), and 30 had eaten species of *Notropis*. The frequency of occurrence of fishes in the food of smallmouth bass from the other two rivers is insignificant in comparison. Seasonal studies of adult diets would no doubt reveal important differences in the feeding habits of the adult smallmouth bass in these rivers. Specimens caught in the Cacapon River in mid-July had consumed adult damselflies to a large extent, and there is little doubt that the time of emergence of various aquatic or terrestrial insects has a great deal to do with the nature of the food of adult smallmouth bass in the Cacapon River and the South Branch. Even in the Shenandoah River large smallmouth bass rise to minute mayflies or small black ants blown into the water from the land. At such times these large smallmouth did not evince much interest in artificial lures offered them, and their feeding was probably more in sport than because of true hunger. In the Shenandoah River there definitely are times when the adult smallmouth bass will not take artificial lures, particularly after several weeks of clear-water conditions. Besides the feeding habits noted above in which the adult smallmouth bass fed on minute insects, there appears to be an additional reason why large smallmouth in the Shenandoah River do not take food well at times. Early in the study of the food of adults it was noted that the viscera of Shenandoah River smallmouth contained large amounts of fat. The difference between the fat content of the viscera of these fish when compared with that of the viscera from Cacapon and South Branch individuals is striking. It is believed that quantitative fat determinations would show a considerable difference in stored energy derived from food in bass of the three rivers. Tables 5 and 6 give the forage ratios and food grade values for the large, or adult, smallmouth bass in the three rivers. The principal purpose of this table has been to show what organisms ordinarily occur in the bottom samples and to depict the importance of the various bottom organisms in the food of the bass. Only bottom foods measured by sampling with a square foot-sampler are included in the table. The averages given are the combined averages for the entire season, or in the case of the riffles, samples from the Shenandoah and South Branch for two seasons—1936 and 1938.

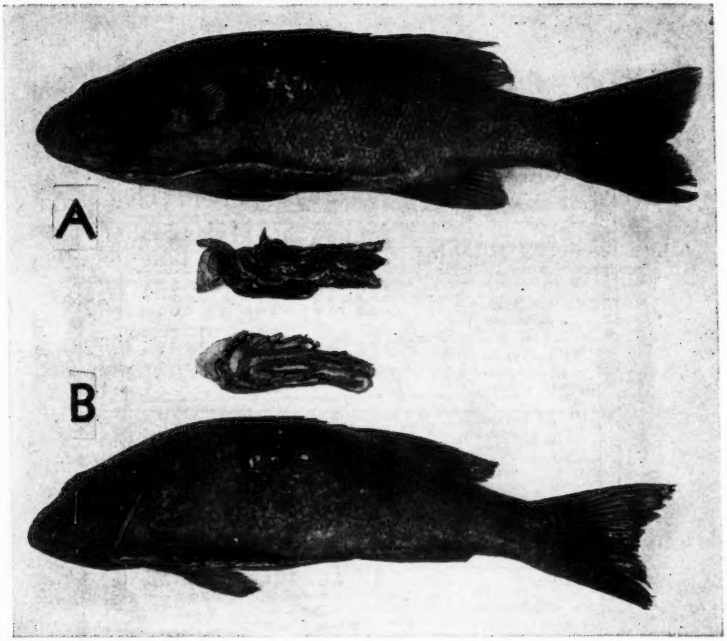

Figure 1.—Viscera of two 12-inch smallmouth black bass illustrating the large difference in the amount of fat. The intestine of the Shenandoah River fish, A, is almost completely hidden from view by fat tissue, while the folds of the intestine of the South Branch bass, B, are exposed. (Photo from material preserved for 1 year.)

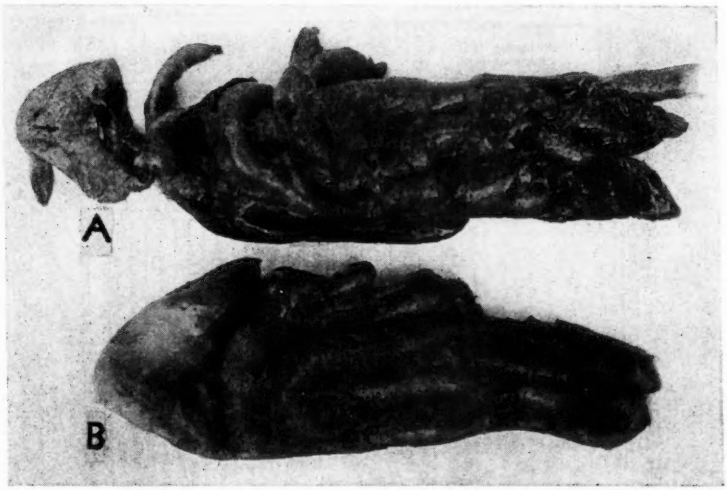

Figure 2.—Enlargements of viscera of smallmouth black bass shown in Figure 1, A, Shenandoah River; B, South Branch, Potomac River.

Table 5.—Bottom fauna of three streams with forage ratios and food grade value for adult smallmouth black bass. (Riffles.)

Item	Cacapon River					Shenandoah River					South Branch of Potomac River				
	Average number organisms per square foot	Percentage of total	Percentage in stomachs	Forage ratios	Food grade values	Average number organisms per square foot	Percentage of total	Percentage in stomachs	Forage ratios	Food grade values	Average number organisms per square foot	Percentage of total	Percentage in stomachs	Forage ratios	Food grade values
Total number of samples	51	....	.....	....	.....	141	....	.....	....	.....	139	....	.....	....	.....
Average number of organisms per square foot	147.50	....	.....	....	.....	132.5	....	.....	....	.....	136.10	....	.....	....	.....
Oligochaeta	1.06	0.72	.....	....	.....	1.7	1.28	.....	....	.....	0.30	0.22	.....	....	.....
Crustacea crayfish (*Cambarus* sp.)	....	....	1.08	....	.....	....	....	4.18	....	.....	....	....	(0.60)	....	.....
Megaloptera (Hellgrammites, orl flies, fish flies)															
Corydalus larvae	0.96	0.65	.....	....	.....	3.2	2.42	2.39	0.99	3.17	1.50	1.10	(0.28)	....	.....
Sialis larvae	0.18	0.12	.....	....	.....	0.5	0.38	.....	....	.....	0.10	0.07	.....	....	.....
Chauliodes larvae	0.56	0.38	.....	....	.....	0.1	0.08	.....	....	.....	0.20	0.15	.....	....	.....
Ephemerida (mayflies)	....	....	(0.69)	....	.....	....	....	.....	....	.....	....	....	1.98	....	.....
Baetis	10.76	7.29	67.33	9.24	10.76	5.0	3.77	2.87	0.76	3.80	7.70	5.66	82.40	14.56	7.70
Heptagenia	20.48	13.88	6.86	0.49	10.04	17.9	13.51	(0.48)	....	.....	22.30	16.39	2.81	0.17	3.79
Isonychia	11.84	8.03	2.00	0.25	2.96	6.6	4.98	33.49	6.72	6.60	22.40	16.46	2.11	0.13	2.91
Ephemerella	1.92	1.30	(0.47)	....	.....	3.1	2.34	.....	....	.....	2.30	1.69	(0.82)	....	.....
Ephemera	3.18	2.16	(0.23)	....	.....	....	....	.....	....	.....	0.60	0.44	.....	....	.....
Ephoron	1.86	1.26	.....	....	.....	4.5	3.40	.....	....	.....	3.30	2.42	.....	....	.....
Potamanthus	0.08	0.05	.....	....	.....	6.2	4.68	1.91	0.41	2.54	0.40	0.29	(0.73)	....	.....
Hexagenia	....	....	.....	....	.....	0.2	0.15	(0.96)	....	.....	....	....	.....	....	.....
Tricorythus	0.18	0.12	.....	....	.....	0.1	0.08	.....	....	.....	....	....	.....	....	.....
Caenis	....	....	.....	....	.....	0.4	0.30	.....	....	.....	0.10	0.07	.....	....	.....
Miscellaneous	0.22	0.15	.....	....	.....	0.6	0.45	.....	....	.....	0.50	0.37	.....	....	.....
Anisoptera (Dragonflies)	0.60	0.41	1.23	3.00	0.60	0.3	0.23	3.35	14.57	0.30	1.30	0.96	(0.41)	....	.....
Zygoptera (Damselflies)	1.10	0.75	6.93	9.24	1.10	1.7	1.28	4.78	3.73	1.70	0.20	0.15	(0.05)	....	.....
Plecoptera (Stoneflies)	6.68	4.53	(0.23)	....	.....	2.2	1.66	(0.96)	....	.....	4.30	3.16	(0.55)	....	.....
Coleoptera (Beetles)	....	....	(0.08)	....	.....	....	....	.....	....	.....	....	....	.....	....	.....
Psephenus larvae	0.82	0.56	.....	....	.....	0.8	0.60	.....	....	.....	0.70	0.51	.....	....	.....
Helichus larvae	0.08	0.05	.....	....	.....	....	....	.....	....	.....	....	....	.....	....	.....
Dineutes and *Gyrinus* larvae	0.06	0.04	(0.54)	....	.....	....	....	.....	....	.....	0.10	0.07	.....	....	.....

Table 5. (Continued)—Bottom fauna of three streams with forage ratios and food grade value for adult smallmouth black bass. (Riffles.)

Item	Cacapon River					Shenandoah River					South Branch of Potomac River				
	Average number organisms per square foot	Percentage of total	Percentage in stomachs	Forage ratios	Food grade values	Average number organisms per square foot	Percentage of total	Percentage in stomachs	Forage ratios	Food grade values	Average number organisms per square foot	Percentage of total	Percentage in stomachs	Forage ratios	Food grade values
Berosus larvae	0.08	0.05	.....	....	.....	0.4	0.30	.....	....	.....	....	....	.....	....	.....
Parnid larvae	14.78	10.02	.....	....	.....	9.6	7.25	.....	....	.....	5.90	4.34	.....	....	.....
Parnid adults	6.28	4.26	.....	....	.....	4.0	3.02	.....	....	.....	1.80	1.32	.....	....	.....
Trichoptera (Caddisflies)															
Hydropsyche larvae	6.66	4.52	.....	....	.....	32.3	24.38	.....	....	.....	14.30	10.51	.....	....	.....
Philopotamus larvae	3.62	2.45	.....	....	.....	0.1	0.08	.....	....	.....	5.10	3.75	.....	....	.....
Neureclipsis larvae	1.56	1.06	.....	....	.....	4.0	3.02	.....	....	.....	1.20	0.88	.....	....	.....
Brachycentrus larvae	23.24	15.76	.....	....	.....	....	....	.....	....	.....	0.20	0.15	.....	....	.....
Miscellaneous larvae	1.46	0.99	(0.08)	....	.....	1.0	0.75	(0.96)	....	.....	0.30	0.22	.....	....	.....
Lepidoptera (Aquatic moths)															
Elophila	....	....	.....	....	.....	2.8	2.11	(0.48)	....	.....	0.40	0.29	.....	....	.....
Diptera (midges, craneflies, etc.)															
Chironomid larvae	2.70	1.83	(0.08)	....	.....	12.4	9.36	(0.48)	....	.....	3.80	2.79	(0.09)	....	.....
Chironomid pupae	0.20	0.14	.....	....	.....	1.7	1.28	.....	....	.....	0.30	0.22	.....	....	.....
Atherix larvae	6.52	4.42	.....	....	.....	....	....	.....	....	.....	0.50	0.37	.....	....	.....
Eriocera larvae	....	....	.....	....	.....	....	....	.....	....	.....	1.50	1.10	.....	....	.....
Simulium larvae	6.64	4.50	.....	....	.....	1.0	0.75	.....	....	.....	0.60	0.44	.....	....	.....
Other cranefly larvae	....	....	.....	....	.....	1.1	0.83	.....	....	.....	0.10	0.07	(0.37)	....	.....
Miscellaneous larvae and pupae	0.04	0.03	.....	....	.....	0.2	0.15	.....	....	.....	0.10	0.07	.....	....	.....
Mollusca (snails and clams)															
Nitrocris	9.22	6.25	(0.39)	....	.....	1.1	0.83	.....	....	.....	31.20	22.92	(0.14)	....	.....
Sphaerium and ***Musculium***	1.16	0.79	.....	....	.....	4.5	3.40	.....	....	.....	0.10	0.07	.....	....	.....
Ancylus	....	....	.....	....	.....	1.0	0.75	.....	....	.....	0.10	0.07	.....	....	.....
Elliptio	0.08	0.05	.....	....	.....	0.1	0.08	.....	....	.....	....	....	.....	....	.....
Miscellaneous mollusks	0.48	0.33	.....	....	.....	0.1	0.08	.....	....	.....	0.30	0.22	(0.05)	....	.....
Miscellaneous organisms	0.16	0.11	.....	....	.....	....	....	.....	....	.....	....	....	.....	....	.....
Totals	147.50	100.01	88.22	....	25.46	132.5	100.0	57.42	....	18.11	136.10	99.98	93.39	....	14.40

Table 6.—Bottom fauna of two streams with forage ratios and food grade values for adult smallmouth black bass. (Pools.)

Item	Shenandoah River					South Branch of the Potomac				
	Average number organisms per square foot	Percentage of total	Percentage in stomachs	Forage ratios	Food grade values	Average number organisms per square foot	Percentage of total	Percentage in stomachs	Forage ratios	Food grade values
Total number of samples	51	.....	.....	.....	.....	50	.....	.....	.....	.....
Average number of organisms per square foot	35.9	.....	.....	.....	.....	82.94	.....	.....	.....	.....
Oligochaeta	1.5	4.18	.....	.....	.....	0.82	0.99	.....	.....	.....
Crustacea: crayfish (*Cambarus* sp.)	.....	.....	4.31	.....	.....	1.10	1.33	(0.60)	.....	.....
Megaloptera (Hellgrammites, orl flies, fish flies										
Corydalus larvae	.....	.....	2.39	.....	.....	0.02	0.02	(0.28)	.....	.....
Sialis larvae	1.2	3.34	.....	.....	.....	2.24	2.70	.....	.....	.....
Ephemerida: (mayflies)	.....	.....	.....	.....	.....	.....	.....	1.98	.....	.....
Baetis	0.4	1.11	2.87	2.59	0.40	4.90	5.91	82.40	13.94	4.90
Heptagenia	2.4	6.69	(0.48)	.....	.....	4.02	4.85	2.81	0.58	2.33
Isonychia	.....	.....	33.49	.....	.....	0.02	0.02	2.11	105.50	0.02
Ephemerella	0.1	0.28	.....	.....	.....	0.22	0.27	(0.82)	.....	.....
Ephemera	.....	.....	.....	.....	.....	2.56	3.09	.....	.....	.....
Ephoron	0.4	1.11	.....	.....	.....	0.26	0.31	.....	.....	.....
Potamanthus	2.2	6.13	1.91	0.31	0.68	2.46	2.97	(0.73)	.....	.....
Hexagenia	3.4	9.47	(0.96)	.....	.....	0.24	0.29	.....	.....	.....
Tricorythus	0.1	0.28	.....	.....	.....	3.26	3.93	.....	.....	.....
Caenis	0.5	1.39	.....	.....	.....	1.10	1.33	.....	.....	.....
Miscellaneous	.....	.....	.....	.....	.....	0.10	0.12	.....	.....	.....
Anisoptera (Dragonflies)	0.2	0.56	3.35	5.98	0.20	0.48	0.58	(0.41)	.....	.....
Zygoptera (Damselflies)	0.3	0.84	4.78	5.69	0.30	0.06	0.07	(0.05)	.....	.....
Plecoptera (Stoneflies)	0.7	1.95	(0.96)	.....	.....	0.38	0.46	(0.55)	.....	.....
Coleoptera (beetles)										
Psephenus larvae	0.3	0.84	.....	.....	.....	0.40	0.48	.....	.....	.....
Dineutes and *Gyrinus* larvae	.....	.....	.....	.....	.....	0.08	0.10	.....	.....	.....
Berosus larvae	0.1	0.28	.....	.....	.....	0.10	0.12	.....	.....	.....
Parnid larvae	0.5	1.39	.....	.....	.....	1.70	2.05	.....	.....	.....
Parnid beetles	1.0	2.79	.....	.....	.....	0.44	0.53	.....	.....	.....
Trichoptera (caddisflies)										
Hydropsyche larvae	0.5	1.39	.....	.....	.....	0.16	0.19	.....	.....	.....
Neureclipsis larvae	0.1	0.28	.....	.....	.....	0.46	0.55	.....	.....	.....
Miscellaneous larvae	0.1	0.28	(0.96)	.....	.....	0.36	0.43	.....	.....	.....
Lepidoptera (aquatic moths)										
Elophila	0.4	1.11	(0.48)	.....	.....	0.02	0.02	.....	.....	.....
Diptera (midges, craneflies, etc.)										
Chironomid larvae	16.5	45.96	(0.48)	.....	.....	51.46	62.04	(0.09)	.....	.....
Chironomid pupae	0.4	1.11	.....	.....	.....	0.40	0.48	.....	.....	.....
Eriocera larvae	.....	.....	.....	.....	.....	0.34	0.41	.....	.....	.....
Simulium larvae	.....	.....	.....	.....	.....	0.08	0.10	.....	.....	.....
Miscellaneous larvae and pupae	0.3	0.84	.....	.....	.....	.....	.....	.....	.....	.....
Mollusca (snails and clams)										
Nitocris	.....	.....	.....	.....	.....	1.58	1.90	(0.14)	.....	.....
Sphaerium and *Musculium*	0.1	0.28	.....	.....	.....	0.40	0.48	.....	.....	.....
Ancylus	.....	.....	.....	.....	.....	0.26	0.31	.....	.....	.....
Elliptio	.....	.....	.....	.....	.....	0.08	0.10	.....	.....	.....
Miscellaneous mollusks	.....	.....	.....	.....	.....	0.06	0.07	.....	.....	.....
Miscellaneous organisms	2.2	6.13	.....	.....	.....	0.32	0.39	(0.05)	.....	.....
Totals	35.9	100.01	57.42	.....	1.58	82.94	99.99	93.32	.....	7.25

In presenting the data in these tables (5 and 6), it has been necessary to list the species of adult mayflies which are unknown to the writer, after the item "Ephemerida: (mayflies)." The generic names of the mayflies under this heading include the nymphal stages under all headings except "Percentage in stomachs," "Forage ratios," and "Food-grade values," where the nymphal and adult stages have been combined.

The data on the food of adult smallmouth bass supports conclusions derived earlier from a study of growth rates by the scale method. It is apparent that fast-growing individuals require an abundance of forage fishes, which are available in the Shenandoah River but not in the Cacapon River and South Branch of the Potomac. The much greater fat content of the viscera of the fast-growing Shenandoah smallmouth bass affords a criterion by which conditions in a stream might be judged through direct examination of the viscera of a series of specimens.

Food of Smallmouth Black Bass Fingerlings

The food of smallmouth bass fingerlings in the Shenandoah River and in the South Branch of the Potomac River is listed in Tables 7-15. These data have been arranged to show seasonal differences, and also the differences which are due to availability of the organisms in the two rivers. The food of smallmouth bass of about the same size collected at the same season are compared, and the food of the smallmouth bass fingerlings from May to September is given. The food of 101 specimens of bass averaging 67.4 millimeters in length from the South Branch of the Potomac River collected on October 27, 1936, was not tabulated since we were unable to obtain sufficient specimens in October from the Shenandoah River for comparison. The chief items of food were *Baetis* (42.08 per cent), Zygoptera (28.21 per cent), and *Heptagenia* nymphs (12.94 per cent). The total number of items found in the stomachs of this lot was 499. Considerable space could be occupied in dealing with the various differences which are apparent from the study. An inspection of the tables will show the facts and the deficiencies of the bottom sampling. The following facts of importance are cited:

1. The early food of smallmouth bass in these rivers differs to a striking degree from the early food reported by such workers as Wickliff (1920) and Tester (1932a) in their studies of the food of young bass collected from lakes. The early food of smallmouth bass in these rivers consisted largely of midge larvae and mayfly nymphs, the latter principally of the genus *Baetis*. Even small fish were important volumetrically in the food of smallmouth bass fry, averaging 10 millimeters in length in the first Shenandoah River collection. As the season advances, fingerling bass feed less on chironomid larvae and

Table 7.—Food, forage ratios, and stream food grades for smallmouth black bass fingerlings in May. (Riffles.)

Item	Shenandoah River, May 13, 1936 Number of specimens examined: 99; average length: 10 millimeters; Range in length: 8.4-12.0 millimeters.						South Branch, Potomac River, May 22, 1936 Number of specimens examined: 84; average length: 12.2 millimeters; Range in length: 10.5-16.0 millimeters.					
	In the stream			In the stomach			In the stream			In the stomach		
	Average number per square foot	Percentage of total	Frequency	Percentage of total diet	Forage ratios	Food grade values	Average number per square foot	Percentage of total	Frequency	Percentage of total diet	Forage ratios	Food grade values
A. Bottom fauna												
Ephemerida (mayflies)												
Baetis	4.25	3.31	43	6.25	1.89	4.25	0.77	3.12	14	(0.87)	.....	.....
Heptagenia	22.10	17.23	3	(0.19)	.....	.....	2.88	11.67	4	(0.72)	.....	.....
Diptera (Midges)												
Chironomid larvae	11.90	9.28	97	78.95	8.51	11.90	1.55	6.28	81	78.15	12.44	1.55
Chironomid pupae	2.05	1.60	19	3.81	2.38	2.05	0.88	3.57	37	16.05	4.50	0.88
Total in table	40.30	31.42	....	.....	.....	.....	6.08	24.64	....	.....	.....	.....
Other bottom fauna	89.43	68.57	....	.....	.....	.....	18.60	75.38	....	.....	.....	.....
Totals	129.73	99.99	....	.....	.....	.....	24.68	100.02	....	.....	.....	.....
Number of bottom samples	20	.....	....	.....	.....	.....	9	.....	....	.....	.....	.....
Potential food grade	.....	.....	....	.....	.....	129.73	.....	.....	....	.....	.....	24.68
Effective food grade	.....	.....	....	.....	.....	18.20	.....	.....	....	.....	.....	2.43
B. Food items not measured by bottom sampling												
Entomostraca (water fleas, etc.)												
Cyclops	.....	.....	25	6.31	.....	.....	.....	.....	20	3.08	.....	.....
Hemiptera (true bugs)												
"Sponson bugs (?)"	.....	.....	10	3.31	.....	.....	.....	.....	3	(0.26)	.....	.....
Vertebrates												
Fish	.....	.....	9	(0.81)	.....	.....	.....	.....	1	(0.05)	.....	.....
Total percentage of food	.....	.....	....	99.63	.....	.....	.....	.....	....	99.18	.....	.....
Total number of items consumed in each collection of bass	.....	.....	....	1,584.60	.....	.....	.....	.....	....	1,637.8	.....	.....

Table 8.—Food, forage ratios, and food grades for smallmouth black bass fingerlings in May. (Pools.)

Item	Shenandoah River, May 13, 1936 Number of specimens examined: 99; average length: 10 millimeters; Range in length: 8.4-12.0 millimeters.						South Branch, Potomac River, May 22, 1936 Number of specimens examined: 84; average length: 12.2 millimeters; Range in length: 10.5-16.0 millimeters.					
	In the stream			In the stomach			In the stream			In the stomach		
	Average number per square foot	Percentage of total	Frequency	Percentage of total diet	Forage ratios	Food grade values	Average number per square foot	Percentage of total	Frequency	Percentage of total diet	Forage ratios	Food grade values
A. Bottom fauna												
Ephemerida (mayflies)												
Baetis	0.20	0.67	43	6.25	9.32	0.20	0.30	1.50	14	(0.87)	.....	.....
Heptagenia	1.50	5.05	3	(0.19)	.....	.....	2.10	10.50	4	(0.72)	.....	.....
Diptera (Midges)												
Chironomid larvae	1.60	5.39	97	78.95	14.65	1.60	9.40	47.00	81	78.15	1.67	9.40
Chironomid pupae	0.90	3.03	19	3.81	1.26	0.90	0.50	2.50	37	16.05	6.42	0.50
Total in table	4.20	14.14	....	.....	.....	.....	12.30	61.50	....	.....	.....	.....
Other bottom fauna	25.50	85.88	....	.....	.....	.....	7.70	38.50	....	.....	.....	.....
Totals	29.70	100.02	....	.....	.....	.....	20.00	100.00	....	.....	.....	.....
Number of bottom samples	11	.....	....	.....	.....	.....	10	.....	....	.....	.....	.....
Potential food grade	.....	.....	....	.....	.....	29.70	.....	.....	....	.....	.....	20.00
Effective food grade	.....	.....	....	.....	.....	2.70	.....	.....	....	.....	.....	9.90
B. Food items not measured by bottom sampling												
Entomostraca (water fleas, etc.)												
Cyclops	.....	.....	25	6.31	.....	.....	.....	.....	20	3.08	.....	.....
Hemiptera (true bugs)												
"Sponson bugs (?)"	.....	.....	10	3.31	.....	.....	.....	.....	....	.....	.....	.....
Vertebrates												
Fish	.....	.....	9	(0.81)	.....	.....	.....	.....	....	.....	.....	.....
Total percentage of food	.....	.....	....	99.63	.....	.....	.....	.....	....	98.87	.....	.....
Total number of items consumed in each collection of bass	.....	.....	....	1,584.60	.....	.....	.....	.....	....	1,637.80	.....	.....

Table 9.—Food, forage ratios, and food grades for smallmouth black bass fingerlings in June. (Riffles.)

Item	Shenandoah River, June 17, 1936 Number of specimens examined: 100; average length: 41.6 millimeters; Range in length: 34.5-54.0 millimeters.						South Branch, Potomac River, June 5, 1936 Number of specimens examined: 109; average length: 28.9 millimeters; Range in length: 24.0-36.5 millimeters.					
	In the stream			In the stomach			In the stream			In the stomach		
	Average number per square foot	Percentage of total	Frequency	Percentage of total diet	Forage ratios	Food grade values	Average number per square foot	Percentage of total	Frequency	Percentage of total diet	Forage ratios	Food grade values
A. Bottom fauna												
Ephemerida (mayflies)												
Baetis	3.50	2.66	23	8.07	3.03	3.50	12.7	10.95	31	20.52	1.87	12.70
Heptagenia	11.50	8.74	7	(0.82)	.....	.....	28.3	24.40	14	6.95	0.28	7.92
Ephoron	18.45	14.02	6	(0.82)	.....	.....	10.7	9.22	6	4.96	0.54	5.78
Potamanthus	5.25	3.99	22	3.39	0.85	4.46	0.7	0.60	3	1.24	2.07	0.70
Diptera (Midges)												
Chironomid larvae	22.65	17.21	26	78.48	4.56	22.65	4.7	4.05	23	34.26	8.46	4.70
Chironomid pupae	3.30	2.51	9	2.81	1.12	3.30	0.6	0.52	4	2.32	4.46	0.60
Total in table	64.65	49.13	....	.....	.....	.....	57.70	49.74	....	.....	.....	.....
Other bottom fauna	66.97	50.97	....	.....	.....	.....	58.30	50.29	....	.....	.....	.....
Totals	131.62	100.10	....	.....	.....	.....	116.00	100.03	....	.....	.....	.....
Number of bottom samples	19	.....	....	.....	.....	.....	32	.....	....	.....	.....	.....
Potential food grade	.....	.....	....	.....	.....	131.62	.....	.....	....	.....	.....	116.00
Effective food grade	.....	.....	....	.....	.....	33.91	.....	.....	....	.....	.....	32.40
B. Food items not measured by bottom sampling												
Entomostraca (water fleas, etc.)												
Cyclops	.....	.....	....	.....	.....	.....	.....	.....	4	1.65	.....	.....
Simocephalus	.....	.....	2	(0.23)	.....	.....	.....	.....	3	1.61	.....	.....
Hemiptera (true bugs)												
Corixidae (nymphs and adults)	.....	.....	11	1.64	.....	.....	.....	.....	....	.....	.....	.....
Vertebrates												
Tadpoles	.....	.....	10	1.40	.....	.....	.....	.....	....	.....	.....	.....
Fish	.....	.....	9	1.40	.....	.....	.....	.....	59	24.41	.....	.....
Total percentage of food	.....	.....	....	99.06	.....	.....	.....	.....	....	97.92	.....	.....
Total number of items consumed in each collection of bass	.....	.....	....	854.30	.....	.....	.....	.....	....	241.7	.....	.....

Table 10.—Food, forage ratios, and food ghades for smallmouth black bass fingerlings in June. (Pools.)

Item	Shenandoah River, June 17, 1936 Number of specimens examined: 100; average length: 41.6 millimeters; Range in length: 34.5-54.0 millimeters.						South Branch, Potomac River, June 5, 1936 Number of specimens examined: 109; average length: 28.9 millimeters; Range in length: 24.0-36.5 millimeters.					
	In the stream			In the stomach			In the stream			In the stomach		
	Average number per square foot	Percentage of total	Frequency	Percentage of total diet	Forage ratios	Food grade values	Average number per square foot	Percentage of total	Frequency	Percentage of total diet	Forage ratios	Food grade values
A. Bottom fauna												
Ephemerida (mayflies)												
Baetis	0.1	0.30	23	8.07	26.90	0.10	15.0	9.02	31	20.52	2.27	15.00
Heptagenia	1.5	4.49	7	(0.82)	.....	.....	8.3	4.99	14	6.95	1.39	8.30
Ephoron	0.8	2.40	6	(0.82)	.....	.....	0.7	0.42	6	4.96	11.81	0.70
Potamanthus	1.7	5.09	22	3.39	0.67	1.14	1.6	0.96	3	1.24	1.29	1.60
Diptera (Midges)												
Chironomid larvae	20.2	60.48	26	78.48	1.30	20.2	106.2	63.86	23	34.26	0.54	57.35
Chironomid pupae	.....	.....	9	2.81	.....	.....	0.5	0.30	4	2.32	7.73	0.50
Total in table	24.30	72.76	....	.....	.....	.....	132.30	79.55	....	.....	.....	.....
Other bottom fauna	9.10	27.26	....	.....	.....	.....	34.00	20.44	....	.....	.....	.....
Totals	33.4	100.02	....	.....	.....	.....	166.3	99.99	....	.....	.....	.....
Number of bottom samples	10	.....	....	.....	.....	.....	10	.....	....	.....	.....	.....
Potential food grade	.....	.....	....	.....	.....	33.4	.....	.....	....	.....	.....	166.30
Effective food grade	.....	.....	....	.....	.....	21.44	.....	.....	....	.....	.....	83.45
B. Food items not measured by bottom sampling												
Entomostraca (water fleas, etc.)												
Cyclops	.....	.....	....	.....	.....	.....	.....	.....	4	1.65	.....	.....
Simocephalus	.....	.....	2	(0.23)	.....	.....	.....	.....	3	1.61	.....	.....
Hemiptera (true bugs)												
Corixidae (nymphs and adults)	.....	.....	11	1.64	.....	.....	.....	.....	....	.....	.....	.....
Vertebrates												
Tadpoles	.....	.....	10	1.40	.....	.....	.....	.....	....	.....	.....	.....
Fish	.....	.....	9	1.40	.....	.....	.....	.....	59	24.41	.....	.....
Total percentage of food	.....	.....	....	99.06	.....	.....	.....	.....	....	97.92	.....	.....
Total number of items consumed in each collection of bass	.....	.....	....	854.3	.....	.....	.....	.....	....	241.7	.....	.....

Table 11.—Food, forage ratios, and food grades for smallmouth black bass fingerlings in July. (Riffles.)

Item	Shenandoah River, July 18, 1936 Number of specimens examined: 72; average length: 57.7 millimeters; Range in length: 46.0-80.0 millimeters.						South Branch, Potomac River, July 23, 1936 Number of specimens examined: 105; average length: 48:5 millimeters; Range in length, 37.5-60.0 millimeters.					
	In the stream			In the stomach			In the stream			In the stomach		
	Average number per square foot	Percentage of total	Frequency	Percentage of total diet	Forage ratios	Food grade values	Average number per square foot	Percentage of total	Frequency	Percentage of total diet	Forage ratios	Food grade values
A. Bottom fauna												
Ephemerida (mayflies)												
Baetis	7.80	6.53	48	32.60	4.99	7.80	18.00	13.95	44	8.47	0.61	10.98
Heptagenia	21.20	17.74	22	6.21	0.35	7.42	23.10	17.91	20	3.72	0.21	4.85
Isonychia	5.10	4.27	...	.....	.....	.....	24.20	18.76	18	3.12	0.17	4.11
Plecoptera (stoneflies)	0.70	0.59	....	.....	.....	.....	4.20	3.26	7	1.03	0.32	1.34
Trichoptera												
Neureclipsis	5.30	4.44	5	2.61	0.59	3.13	0.80	0.62	....	.....	.....	.....
Diptera (Midges)												
Chironomid larvae	12.40	10.38	43	53.46	5.15	12.40	2.50	1.94	60	60.86	31.37	2.50
Total in table	52.50	43.95	....	.....	.....	.....	72.80	56.44	....	.....	.....	.....
Other bottom fauna	67.00	56.03	....	.....	.....	.....	56.20	43.53	....	.....	.....	.....
Totals	119.50	99.98	....	.....	.....	30.75	129.00	99.97	....	.....	.....	23.78
Number of bottom samples	21	.....	....	.....	.....	.....	20	.....	....	.....	.....	.....
Potential food grade	.....	.....	....	.....	.....	119.50	.....	.....	....	.....	.....	129.00
Effective food grade	.....	.....	....	.....	.....	30.75	.....	.....	....	.....	.....	23.78
B. Food items not measured by bottom sampling												
Entomostraca (water fleas, etc.)												
Cyclops	.....	.....	2	(0.21)	.....	.....	.....	.....	8	10.27	.....	.....
Simocephalus	.....	.....	5	1.31	.....	.....	.....	.....	....	.....	.....	.....
Hemiptera (true bugs)	.....	.....	....	.....	.....	.....	.....	.....	....	.....	.....	.....
Corixidae (nymphs and adults)	.....	.....	3	(0.31)	.....	.....	.....	.....	25	10.11	.....	.....
Vertebrates												
Fish	.....	.....	....	.....	.....	.....	.....	.....	5	(0.32)	.....	.....
Total percentage of food	.....	.....	....	96.71	.....	.....	.....	.....	....	97.90	.....	.....
Total number of items consumed in each collection of bass	.....	.....	....	957.20	.....	.....	.....	.....	....	1,557.70	.....	.....

Table 12.—Food, forage ratios, and food grades for smallmouth black bass fingerlings in July. (Pools.)

Item	Shenandoah River, July 18, 1936. Number of specimens examined: 72; average length: 57.7 millimeters; Range in length: 46.0-80.0 millimeters.						South Branch, Potomac River, July 23, 1936. Number of specimens examined: 105; average length: 48:5 millimeters; Range in length, 37.5-60.0 millimeters.					
	In the stream			In the stomach			In the stream			In the stomach		
	Average number per square foot	Percentage of total	Frequency	Percentage of total diet	Forage ratios	Food grade values	Average number per square foot	Percentage of total	Frequency	Percentage of total diet	Forage ratios	Food grade values
A. Bottom fauna												
Ephemerida (mayflies)												
Baetis	1.4	3.25	48	32.60	10.03	1.4	8.2	6.80	44	8.47	1.25	8.2
Heptagenia	2.5	5.80	22	6.21	1.07	2.5	2.3	1.91	20	3.72	1.95	2.3
Isonychia	.....	.....	....	.....	.....	.....	.....	.....	18	3.12	.....	.....
Plecoptera (stoneflies)	0.3	0.70	....	.....	.....	.....	0.2	0.17	7	1.03	6.06	0.2
Trichoptera												
Neureclipsis	0.2	0.46	5	2.61	5.67	0.2	1.0	0.83	....	.....	.....	.....
Diptera (Midges)												
Chironomid larvae	22.5	52.20	43	53.46	1.02	22.5	78.9	65.42	60	60.86	0.93	73.4
Total in table	26.90	62.41	....	.....	.....	.....	90.60	75.13	....	.....	.....	.....
Other bottom fauna	16.20	37.56	....	.....	.....	.....	30.00	24.87	....	.....	.....	.....
Totals	43.1	99.97	....	.....	.....	.....	120.6	100.00	....	.....	.....	.....
Number of bottom samples	10	.....	....	.....	.....	.....	10	.....	....	.....	.....	.....
Potential food grade	.....	.....	....	.....	.....	43.1	.....	.....	....	.....	.....	120.6
Effective food grade	.....	.....	....	.....	.....	26.6	.....	.....	....	.....	.....	84.1
B. Food items not measured by bottom sampling												
Entomostraca (water fleas, etc.)												
Cyclops	.....	.....	2	(0.21)	.....	.....	.....	.....	8	10.27	.....	.....
Simocephalus	.....	.....	5	1.31	.....	.....	.....	.....	....	.....	.....	.....
Hemiptera (true bugs)												
Corixidae (nymphs and adults)	.....	.....	3	(0.31)	.....	.....	.....	.....	25	10.11	.....	.....
Vertebrates												
Fish	.....	.....	....	.....	.....	.....	.....	.....	5	(0.32)	.....	.....
Total percentage of food	.....	.....	....	96.71	.....	.....	.....	.....	....	97.90	.....	.....
Total number of items consumed in each collection of bass	.....	.....	....	957.2	.....	.....	.....	.....	....	1,557.7	.....	.....

Tabue 13.—Food, forage ratios, and food grades for smallmouth black bass fingerlings in August. (Riffles.)

Item	Shenandoah River, August 18, 1936 Number of specimens examined: 109; average length. 79.40 millimeters; Range in length: 60.0-142.0 millimeters.						South Branch, Potomac River, August 24, 1936 Number of specimens examined: 107; average length: 79.3 millimeters; Range in length: 48.0-127.0 millimeters.					
	In the stream			In the stomach			In the stream			In the stomach		
	Average number per square foot	Percentage of total	Frequency	Percentage of total diet	Forage ratios	Food grade values	Average number per square foot	Percentage of total	Frequency	Percentage of total diet	Forage ratios	Food grade values
A. Bottom fauna												
Ephemerida (mayflies)												
Baetis	11.0	8.44	80	72.05	8.54	11.00	11.8	8.23	69	58.61	7.12	11.80
Heptagenia	26.0	19.95	32	4.48	0.22	5.72	19.4	13.54	51	13.33	0.98	19.01
Isonychia	7.2	5.53	10	1.01	0.18	1.30	21.3	14.87	9	3.90	0.26	5.54
Coleoptera (beetles)												
Laccophilus	.....	.....	....	.....	.....	.....	.....	.....	5	1.23	.....	.....
Trichoptera												
Neureclipsis	2.3	1.77	10	1.12	0.63	1.45	1.4	0.98	....	.....	.....	.....
Brachycentrus	0.1	0.08	15	1.68	21.00	0.10	.....	.....	....	.....	.....	.....
Diptera (Midges)												
Chironomid larvae	1.50	1.15	52	16.29	14.17	1.50	3.9	2.72	26	14.23	5.23	3.90
Chironomid pupae	0.23	0.23	....	.....	.....	.....	0.1	0.07	4	1.14	16.29	0.10
Total in table	48.33	37.15	....	.....	.....	.....	57.90	40.41	....	.....	.....	.....
Other bottom fauna	81.97	62.84	....	.....	.....	.....	85.40	59.63	....	.....	.....	.....
Totals	130.30	99.99	....	.....	.....	.....	143.30	100.04	....	.....	.....	.....
Number of bottom samples	20.0	.....	....	.....	.....	.....	19	.....	....	.....	.....	.....
Potential food grade	.....	.....	....	.....	.....	130.30	.....	.....	....	.....	.....	143.30
Effective food grade	.....	.....	....	.....	.....	21.07	.....	.....	....	.....	.....	40.35
B. Food items not measured by bottom sampling												
Hemiptera (true bugs)												
Corixidae (nymphs and adults)	.....	.....	....	.....	.....	.....	.....	.....	7	5.77	.....	.....
Gerridae (*Trepobates*)	.....	.....	21	2.82	.....	.....	.....	.....	....	.....	.....	.....
Vertebrates												
Fish	.....	.....	5	(0.28)	.....	.....	.....	.....	6	(0.49)	.....	.....
Total percentage of food	.....	.....	....	99.73	.....	.....	.....	.....	....	98.70	.....	.....
Total number of items consumed in each collection of bass	.....	.....	....	1,787.6	.....	.....	.....	.....	....	1,224.4	.....	.....

Table 14.—Food, forage ratios, and food grades for sm allmouth black bass fingerlings in September. (Riffles.)

Item	Shenandoah River, September 22, 1936 Number of specimens examined: 95; average length: 86.3 millimeters; Range in length: 71.0-120.0 millimeters.						South Branch Potomac River, September 25, 1936 Number of specimens examined: 95; average length: 69.4 millimeters; Range in length: 57.0-119.0 millimeters.					
	In the stream			In the stomach			In the stream			In the stomach		
	Average number per square foot	Percentage of total	Frequency	Percentage of total diet	Forage ratios	Food grade values	Average number per square foot	Percentage of total	Frequency	Percentage of total diet	Forage ratios	Food grade values
A. Bottom fauna												
Ephemerida (mayflies)												
Baetis	7.1	4.35	36	79.61	18.30	7.10	4.8	2.19	60	61.13	27.91	4.80
Heptagenia	8.1	4.96	4	1.08	0.22	1.78	25.3	11.53	12	(0.97)	.....	.....
Isonychia	7.7	4.72	....	.....	.....	.....	40.2	18.32	9	1.02	0.06	2.41
Ephemera	.....	.....	....	.....	.....	.....	0.5	0.23	7	1.98	8.61	0.50
Diptera (Midges)												
Chironomid larvae	15.9	9.74	6	5.34	0.55	8.75	3.1	1.41	28	6.57	4.66	3.1
Chironomid pupae	0.1	0.06	9	2.43	40.50	0.10	.....	.....	10	23.29	.....	.....
Dixa midge larvae	.....	.....	13	3.51	.....	.....	.....	.....	6	2.18	.....	.....
Total in table	38.90	23.83	....	.....	.....	.....	73.90	33.68	....	.....	.....	.....
Other bottom fauna	124.30	76.15	....	.....	.....	.....	145.50	66.35	....	.....	.....	.....
Totals	163.2	99.98	....	.....	.....	.....	219.4	100.03	....	.....	.....	.....
Number of bottom samples	20	.....	....	.....	.....	.....	20	.....	....	.....	.....	.....
Potential food grade	.....	.....	....	.....	.....	163.20	.....	.....	....	.....	.....	219.40
Effective food grade	.....	.....	....	.....	.....	17.73	.....	.....	....	.....	.....	10.81
B. Food items not measured by bottom sampling												
Entomostraca (water fleas, etc.)												
Cyclops	.....	.....	1	(0.27)	.....	.....	.....	.....	13	2.63	.....	.....
Vertebrates												
Fish	.....	.....	24	7.77	.....	.....	.....	.....	....	.....	.....	.....
Total percentage of food	.....	.....	....	100.01	.....	.....	.....	.....	....	99.77	.....	.....
Total number of items consumed in each collection of bass	.....	.....	....	370.8	.....	.....	.....	.....	....	1.236.8	.....	.....

Table 15.—Food, forage ratios, and food grades for smallmouth black bass fingerlings in September. (Pools.)

Item	Shenandoah River, September 22, 1936 Number of specimens examined: 95; average length: 86.3 millimeters; Range in length: 71.0-120.0 millimeters.						South Branch Potomac River, September 25, 1936 Number of specimens examined: 95; average length: 69.4 millimeters; Range in length: 57.0-119.0 millimeters.					
	In the stream			In the stomach			In the stream			In the stomach		
	Average number per square foot	Percentage of total	Frequency	Percentage of total diet	Forage ratios	Food grade values	Average number per square foot	Percentage of total	Frequency	Percentage of total diet	Forage ratios	Food grade values
A. Bottom fauna												
Ephemerida (mayflies)												
Baetis	0.1	0.31	36	79.61	256.81	0.10	1.0	2.06	60	61.13	29.67	1.00
Heptagenia	1.6	4.94	4	1.08	0.22	0.35	6.6	13.61	12	(0.97)	.....	.....
Isonychia	0.1	0.31	....	.....	.....	.....	0.1	0.21	9	1.02	4.86	0.10
Ephemera	.....	.....	....	.....	.....	.....	3.3	6.80	7	1.98	0.29	0.96
Diptera (Midges)												
Chironomid larvae	7.8	24.07	6	5.34	0.22	1.72	16.4	33.81	28	6.57	0.19	3.12
Chironomid pupae	0.4	1.23	9	2.43	1.98	0.40	0.4	0.82	10	23.29	28.40	0.40
Dixa midge larvae	.....	.....	13	3.51	.....	.....	.....	.....	6	2.18	.....	.....
Total in table	10.0	30.86	....	.....	.....	.....	27.80	57.31	....	.....	.....	.....
Other bottom fauna	22.4	69.14	....	.....	.....	.....	20.70	42.67	....	.....	.....	.....
Totals	32.4	100.00	....	.....	.....	.....	48.5	99.98	....	.....	.....	.....
Number of bottom samples	10.0	.....	....	.....	.....	.....	10	.....	....	.....	.....	.....
Potential food grade	.....	.....	....	.....	.....	32.40	.....	.....	....	.....	.....	48.50
Effective food grade	.....	.....	....	.....	.....	2.57	.....	.....	....	.....	.....	5.58
B. Food items not measured by bottom sampling												
Entomostraca (water fleas, etc.)												
Cyclops	.....	.....	1	(0.27)	.....	.....	.....	.....	13	2.63	.....	.....
Vertebrates												
Fish	.....	.....	24	7.77	.....	.....	.....	.....	....	.....	.....	.....
Total percentage of food	.....	.....	....	100.01	.....	.....	.....	.....	....	99.77	.....	.....
Total number of items consumed in each collection of bass	.....	.....	....	370.8	.....	.....	.....	.....	....	1.236.8	.....	.....

pupae, *Baetis, Heptagenia,* and *Isonychia* nymphs remain the food staples throughout the first growing season.

2. Bottom sampling has failed to a large extent to measure food eaten by bass. While it is probable that *Baetis* dwells to a considerable extent upon aquatic vegetation, it seems that the bottom samples should have shown a larger number of chironomid larvae, the presence of which would have brought about higher effective food grade values. Perhaps the use of a net of finer mesh would have brought about closer correlations. Bottom sampling in bass streams, regardless of low effective food grades, is valuable in comparing the richness of one stream with another. The gradient of a bass stream, as well as the bottom fauna, is probably a factor of great importance than has been recognized in the past. It determines the length of riffles and pools, and streams such as the Shenandoah River, with frequent riffles, unquestionably produce greater quantities of food organisms than streams with infrequent riffles.

3. Considering both adult and fingerling food, the average effective food grades for pools (33.70 per cent of the potential food grades) are generally higher than the effective food grades for riffles (average 17.30 per cent of the potential food grades). When the effective food grades for pools, considering fingerling smallmouth bass alone, in the Shenandoah River were compared with those for pools in the South Branch of the Potomac, however, no significant difference was found. Effective food grades for riffles were generally higher in the Shenandoah River than in the South Branch of the Potomac River. This indicates that the riffles of the Shenandoah River are greater food producing areas.

4. The difference between the food preferences of fingerling smallmouth bass in both rivers are small in comparison to the food of the adults. In both the Shenandoah River and South Branch of the Potomac River the fingerlings feed upon the same staples, which are chiefly chironomid larvae, *Baetis, Heptagenia,* and *Isonychia* nymphs, and occasionally fish.

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WINTER AND SUMMER GROWTH OF BLUEGILLS IN FERTILIZED PONDS[1]

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ABSTRACT

The use of fertilizers to increase the production of fish in ponds has become widespread in recent years. Since fish are cold-blooded animals, their metabolic activities are slowed by cold weather and accelerated by hot weather. Experiments were conducted to study the winter and summer growth of bluegill bream. In December, small fertilized ponds were stocked with bluegill fingerlings at the rate of 1,750 per acre, individuals averaging 3.8 grams in weight. Three months later their average weight had increased to 11.4 grams, a gain of 200 per cent. The water temperature during this period varied from 3° C. in January to 15° C. in March. Another fertilized pond was stocked in March at the rate of 1,500 fingerlings per acre, individuals averaging 4.5 grams in weight. Samples of bream taken from this pond in June averaged 80 grams, a gain of 1,700 per cent. The water temperature during the latter period ranged from 19° C. to 24° C.

Thus, bream do grow during the winter in the South, but the growth is so slow that winter fertilization of ponds generally is not practical. Ponds stocked in the fall or winter should be fertilized lightly during this period to produce sufficient food to support the fish until spring.

INTRODUCTION

Fish are cold-blooded animals, and therefore their body temperature is about the same as that of the surrounding medium. They grow very slowly or cease growth entirely during the winter when the water is sufficiently cold, and the various life processes of the animal are at a low ebb. Belding (1928) stated, "Irrespective of food supply fish culturists have demonstrated that within certain limits fry and fingerling trout grow more slowly in cold water than in warm." Hathaway (1927) found that bluegills (*Lepomis macrochirus*) and largemouth black bass (*Micropterus salmoides*) consumed about one-third as much food at 10° C. (50° F.) as at 20° C. (68° F.). Markus (1932) studied the feeding habits, rate of digestion and growth of largemouth black bass at different temperatures during a 3-month period. He found that the bass fed voluntarily at temperatures of 16° C. (60.8° F.) and above but not at 10° C. and 4° C. (50° and 39.2° F., respectively). Even when force-fed, the bass did not increase in length at the lower temperatures and most of them lost weight. They gained in weight and length at temperatures of 12° to 20° C. (53.6° to 68° F.).

The scales of crappie (*Pomoxis nigro-maculatus* and *P. annularis*), black bass, and bluegill bream collected in Alabama show well-defined annuli, indicating that growth is retarded during the relatively mild winters of this region. The rapid increase in the use of commercial

[1]Published with the approval of the Director.

fertilizers for ponds in recent years (Swingle and Smith, 1939) makes it desirable to ascertain whether the growth of pondfishes is sufficiently retarded by cold weather to make winter fertilization inadvisable.

Winter Experiments

Three ponds were stocked (December 15, 1937) with bluegill fingerlings at the rate of 1,750 per acre. The average weight of the fingerlings used in stocking was 3.8 grams. The experiment was conducted during the 3-month period from December 15, 1937, to March 14, 1938. The ponds received the following treatments: Pond 1 was an unfertilized control; Pond 2 received 160 pounds of ammonium sulfate, 240 pounds of superphosphate (16 per cent), 20 pounds of muriate of potash, and 120 pounds of basic slag per acre every 4 weeks; Pond 3 received twice the above amounts of the same fertilizers every 4 weeks. Heavy applications of fertilizers were used to insure a good growth of plankton during the winter.

The water temperature was taken at intervals during the experiment. The reading was 13° C. (55.4° F.) on December 31; 8° C. (46.4° F.) on January 14; 3° C. (37.4° F.) on January 28; 12.5° C. (54° F.) on February 25; and 15° C. (59° F.) on March 11. Although daily water temperatures were not obtained, a comparison of the air temperatures with the official daily air temperatures indicates that the temperatures on the sampling dates were representative for the period. At 10° C. (50° F.) Hathaway (1927) found bluegills and bass fed sparingly and Markus (1932) found bass stopped feeding. The temperature in the ponds fell below 10° C. during part of the experiment but ranged a few degrees higher most of the time. The ponds were drained on March 14, 1938, and the average weight of the fingerlings was determined. The bluegill bream in unfertilized Pond 1 averaged 3.8 grams; they had not increased in weight. Those in Pond 2 averaged 9.5 grams, a gain of 150 per cent, and the ones in Pond 3 averaged 11.4 grams, an increase of 200 per cent (Figure 1).

Spring and Summer Experiments

Data for comparing spring growth with winter growth were obtained from a fertilized pond stocked March 24, 1938, with bluegill fingerlings at the rate of 1,500 per acre, each averaging 4.5 grams in weight. Although the number of bluegill bream used in stocking this pond was slightly less than that used in the winter experiment, the fish were slightly larger, making the total weights of fish placed in the ponds about the same. The ponds for the winter experiment were stocked at the rate of 6,650 grams per acre and the one for the spring experiment at the rate of 6,750 grams.

The pond was fertilized on April 16, April 23, April 27, and May 27. Each application consisted of 40 pounds of ammonium sulfate, 60

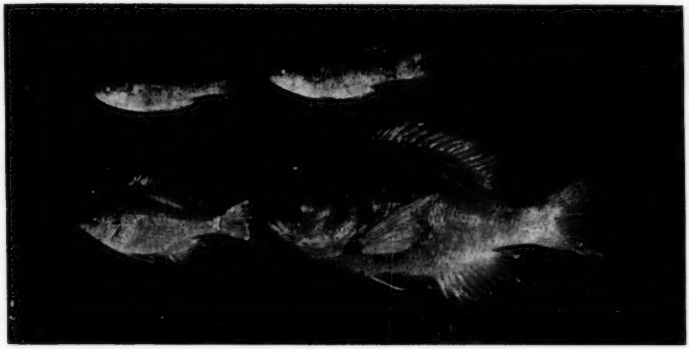

Figure 1.—Effect of temperature on the growth of bluegills. Upper left, average size of fish used in stocking winter experiment. Lower left, average size of the fish in fertilized ponds at end of winter experiments. Upper right, average size fish at the beginning, and, lower right, average size at the end of the spring experiment.

pounds of superphosphate, 5 pounds of muriate of potash, and 30 pounds of basic slag per acre.

The temperature of the water was 20° C. (68° F.) on April 16; 23° C. (73.4° F.) on May 6; 25° C. (77° F.) on May 20, and 24° (75.2° F.) on June 3. It ranged around the temperature, 22° C. (71.6° F.) at which Markus (1932) found bass to digest food fairly rapidly, and somewhat above the temperature, 20° C. (68° F.) at which Hathaway (1928) found bluegills and bass to have a rather high food requirement.

Representative samples of bluegill bream taken from this pond on June 15 averaged 80 grams. During the three warm months, these bream had increased in weight almost 1,700 per cent (Figure 1). The ponds used in the two experiments were stocked with approximately the same number, sizes, and total weight of fish. The results show that although bream do grow in winter at the latitude of Auburn, Alabama, they grow much more rapidly during warm weather.

Much greater percentage increases in growth may be obtained in fertilized ponds during the warm part of the year, provided smaller fish are used in stocking and the total weight of fish placed in the pond is far below the carrying capacity of the pond. For example, a fertilized pond was stocked May 22, 1936, with bluegill bream fry at the rate of 1.9 pounds per acre, the fry averaging 0.034 grams. The pond was drained November 17, 1936, and 358 pounds of fish was obtained. The total weight of fish had increased from 1.9 to 358 pounds in one growing season, an increase of 18,700 per cent. If all of the

bluegill bream placed in the pond had lived, the percentage increase in weight of the individual would have been of the same magnitude; actually, there was a mortality of 23 per cent, raising the gain for the survivors to about 23,700 per cent.

Summary

1. Bluegill bream continue to grow during the winter in fertilized ponds at the latitude of Auburn, Alabama. Gains of 150 to 200 per cent in average weight of the fish were obtained in these experiments.

2. Bluegill bream in fertilized ponds grew much more rapidly during the spring than during the winter months. Bluegills in a pond stocked in the spring at a rate comparable to those for the winter experiment made gains of approximately 1,700 per cent.

3. Since fish grow very slowly during the cold months, it usually is inadvisable to fertilize ponds during the winter.

4. Ponds stocked in the fall or winter should be fertilized sufficiently during this period to support the fish until spring.

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EXPERIMENTAL STUDY OF THE EFFECT OF VARIOUS WATER TEMPERATURES ON THE GROWTH, FOOD UTILIZATION, AND MORTALITY RATES OF FINGERLING SOCKEYE SALMON

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ABSTRACT

Experiments were conducted with sockeye salmon fingerlings to determine the effect of various water temperatures on the growth, mortality, and food conversion of the fish. Maximum tolerance temperatures were determined, as were the optimum growth zones, as found in Skaha Lake, British Columbia, during the summer and fall months. The experimental data tend to confirm the field observations that young sockeye salmon have a preference for water temperatures similar to those found near the thermocline during the summer and fall months. The temperature of the surface layer of water in the lake was too high for optimum growth, survival, and efficient utilization of food.

INTRODUCTION

The sockeye salmon (*Oncorhynchus nerka* Walbaum) is an anadromous fish that spends a part of its life cycle feeding in fresh-water lakes, and a part in the sea. The fresh-water feeding period is usually of one or more years' duration and it is during this fresh-water stage that the species comes directly under the influence of man's activities. The blocking of streams and the consequent prevention of migration to the natural spawning grounds often makes it necessary to transplant the runs of fish to a new environment.

Many research workers have assumed that a definite relationship exists between the temperature of the lake water, in which the young sockeye salmon spend their feeding stage, and the well-being and survival of the fish. To date, however, little experimental evidence has become available to serve as a measure of the influence of the water temperature.

The experiments that form the basis of this report were designed to reproduce some of the temperature variations found in lakes that at one time supported runs of sockeye salmon. In addition to the lake temperatures duplicated, additional tanks containing fish were used as controls, and to ascertain the maximum water temperatures the young fish would be able to withstand.

The experiments were conducted in the experimental hatchery of the School of Fisheries, University of Washington. The field data used were gathered by the former Bureau of Fisheries[1] during work in the Columbia River Basin.

Equipment

The University of Washington Experimental Hatchery has six tanks, each provided with a flow of 1½ gallons of water per minute. The water may be delivered to each tank at any desired temperature from 34° F. to 100° F. The contents of each tank may be maintained at any desired temperature ± 1° F. by the action of thermostatically controlled mixing valves.

The water temperatures in each tank were recorded by Bristol recording thermometers that operated on weekly recording sheets graduated at intervals of 1° F. These laboratory recorders were of the same manufacture and style as those used in making the field recordings, so that, in duplicating the field conditions in the laboratory, the field data were traced on the recorder sheets with pencil and the temperatures regulated to follow the tracings.

Sockeye salmon fingerlings from the U. S. Fisheries Station, Birdsview, Washington, were used in the experiments. The fish were from the Baker Lake, Washington, stock, and were hatched and then reared at the Birdsview Station until the beginning of the experiment.

Experiments

The experiments were begun on July 10, 1939, with 100 sockeye fingerlings in each of the six tanks.

The fish in all lots were weighed at 2-week intervals and the total weights of the fish remaining alive at the various time intervals are recorded in Table 1. The total increases in weight of live fish for each interval are given in Table 2; mortalities are recorded in Table 3, and the amounts of food consumed are summarized in Table 4. The food used for all the lots during the experiments was a mixture composed of 70 per cent fresh beef liver and 30 per cent Quilcene salmon meal. The fish were fed once each day and at each feeding were given all the food they would consume without waste. The utilization of the food by the fish is expressed as efficiency factors in Table 5. The values given are the unit weights of live fish produced by a like unit weight of the food mixture.

The fish in Tank No. 1 were used as a control lot. The temperatures in this tank followed the variations in the city water supply. The temperatures experienced by the fish in this lot appear in the summary of temperatures, Table 7.

[1]Under the provisions of the President's Reorganization Plan No. III, effective June 30, 1940, the Bureau of Fisheries and the Bureau of Biological Survey were consolidated to form the Fish and Wildlife Service of the U. S. Department of the Interior.

Table 1.—Total weights of fish in grams in tanks weighed at 2-week intervals

Date (1939)	Tank No.					
	1	2	3	4	5	6
July 10[1]	227	240	224	234	230	243
July 25	252	202	237	261	259	276
August 8	286	217	222	288	285	307
August 22	338	240	206	282	308	374
September 5	386	245	184	285	354	426
September 19	437	286	215	318	397	486
October 3	497	364	292	385	475	552
October 17	554	418	355	440	566	631
October 31	624	464	420	500	634	711
November 14	719	570	520	603	703	830
November 28	751	606	563	637	727	868
December 12	827	671	652	700	743	953
Total increase in weight	600	431	428	466	513	710

[1]Initial weight of fish.

Table 2.—Total gain or loss in weight in grams of live fish produced each 2-week period

Date (1939)	Tank No.					
	1	2	3	4	5	6
July 10	0	0	0	0	0	0
to July 25	25	—38	13	27	29	33
to August 8	34	15	—15	27	26	31
to August 22	52	23	—16	—6	23	67
to September 5	48	5	—22	3	46	52
to September 19	51	41	31	33	43	60
to October 3	60	78	77	67	78	66
to October 17	57	54	63	55	91	79
to October 31	70	46	65	60	68	80
to November 14	95	106	100	103	69	119
to November 28	32	36	43	34	24	38
to December 12	76	65	89	63	16	85
Total increase in weight	600	431	428	466	513	710

Table 3.—Mortality by 2-week intervals

Date (1939)	Tank No.					
	1	2	3	4	5	6
July 10[1]	100	100	100	100	100	100
to July 25	0	4	0	0	0	0
to August 8	0	0	1	0	0	0
to August 22	0	0	3	4	0	0
to September 5	0	5	15	3	0	0
to September 19	1	3	3	1	0	0
to October 3	0	0	3	0	0	0
to October 17	0	5	1	0	0	0
to October 31	0	5	2	2	0	0
to November 14	2	1	0	1	1	0
to November 28	2	2	0	1	1	0
to December 12	0	1	0	4	3	0
Total mortality	5	26	28	16	5	0

[1]Initial number of fish.

Table 4.—Food consumed by 2-week intervals expressed in grams

Date (1939)	Tank No.					
	1	2	3	4	5	6
July 10 to July 25	100	60	100	100	100	100
to August 8	100	76	63	100	100	100
to August 22	100	100	58	100	100	100
to September 5	130	100	73	110	130	130
to September 19	130	120	110	130	130	130
to October 3	160	160	160	160	160	160
to October 17	200	200	200	200	200	200
to October 31	200	200	200	200	200	200
to November 14	215	215	215	215	215	215
to November 28	170	170	170	170	170	170
to December 12	180	180	180	180	145	180
Total	1,685	1,581	1,529	1,665	1,650	1,685

Table 5.—Efficiency factors[1] by 2-week intervals

Date (1939)	Tank No.					
	1	2	3	4	5	6
July 10 to July 25	0.25	.....	0.13	0.27	0.29	0.33
to August 8	0.34	0.20	.....	0.27	0.26	0.31
to August 22	0.52	0.23	.....	.....	0.23	0.67
to September 5	0.37	0.05	.....	0.03	0.35	0.40
to September 19	0.39	0.34	0.28	0.25	0.33	0.46
to October 3	0.38	0.49	0.48	0.42	0.49	0.41
to October 17	0.29	0.27	0.32	0.28	0.46	0.40
to October 31	0.35	0.23	0.33	0.30	0.34	0.40
to November 14	0.44	0.49	0.47	0.48	0.32	0.55
to November 28	0.19	0.21	0.25	0.20	0.14	0.22
to December 12	0.42	0.36	0.49	0.35	0.11	0.47

[1]Efficiency factor $= \frac{\text{weight of fish produced}}{\text{weight of food fed}}$.

Table 6.—Average weight in grams of sockeye salmon in temperature experiments, at 2-week intervals

Date (1939)	Tank No.					
	1	2	3	4	5	6
July 10[1]	2.27	2.40	2.24	2.34	2.30	2.43
July 25	2.52	2.10	2.37	2.61	2.59	2.76
August 8	2.86	2.26	2.24	2.88	2.85	3.07
August 22	3.38	2.50	2.15	2.94	3.08	3.74
September 5	3.86	2.69	2.27	3.06	3.54	4.26
September 19	4.41	3.25	2.76	3.46	3.97	4.86
October 3	5.02	4.14	3.89	4.18	4.75	5.52
October 17	5.60	5.04	4.80	4.78	5.66	6.31
October 31	6.30	5.95	5.83	5.56	6.34	7.11
November 14	7.41	7.40	7.22	6.78	7.10	8.30
November 28	7.91	8.08	7.82	7.24	7.42	8.68
December 12	8.71	9.07	9.06	8.33	7.82	9.53

[1]Initial weights.

The fish in tank No. 2 were used to ascertain the maximum temperatures the fish would withstand. The water temperatures in this tank were gradually raised from 63° F. to 78° F., during the first week of the experiment. Since at temperatures near 78° F. the fish refused to eat and the respiration rate became excessive, the temperature was lowered to approximately 70° F. and maintained at that level from July 19 to September 5, when the temperature was lowered to that of Tank No. 1 (Table 7). At temperatures above 70° F. the fish lost weight (Tables 1 and 6); with average temperatures of 70° F. the fish were able to make a very slight increase in weight. Growth, as measured by increase in weight, was faster after September 5, at which time the temperatures were lowered to those of the city water.

During the first week of the experimental period the fish in Tank No. 3 were subjected to water temperatures that were increased from 63° F. to 73° F. Following this initial rise in temperature, the water in this tank was maintained at 73° F. until September 5. During this interval the fish lost weight, mortality was high, and utilization of food was poor. After September 5 the temperature was lowered to that of the city water (62° F. to 53° F.), the fish resumed growth, mortalities declined, and the utilization of food resumed the normal trend.

The fish in Tank No. 4 were maintained in water temperatures similar to those in Tank No. 1 from July 10 to August 10. Beginning August 11 the water temperatures were maintained at or near those of the surface water temperatures of Skaha Lake, B. C. The water temperatures were first recorded in Skaha Lake, July 31, 1939. After a week's data had been tabulated the records were forwarded to Seattle and the experimental lots of fish were subjected to a duplication of this water temperature. The last recordings were received from Skaha Lake on November 28, and their reproduction in tanks completed on December 12.

Water maintained at the surface temperatures of Skaha Lake during early August was too warm for successful rearing of sockeye salmon fingerlings. The fish lost weight, mortality increased, and utilization of the food was poor. With the decline of the lake temperatures during September into the range between 70° F. and 60° F. the growth rate of the fish increased. With a further decline in the water temperature during October to between 63° F. and 53° F., the rate of growth was greatly accelerated.

The sockeye salmon fingerlings confined to Tank No. 5 were held in conditions similar to those in Tank No. 4 except that from August 11 to the termination of the experiment the temperatures in Tank No. 5 were held 5° F. below those of Tank No. 4 (surface temperature of Skaha Lake).

In general, the fish held in this colder water (Tank No. 5) grew faster, utilized food more efficiently, and experienced less mortality than did those fish confined in Tank No. 4, in which the water temperature was maintained the same as that at the surface of the lake.

Table 7.—Average maximum and minimum water temperatures, ° F., in the various experimental tanks during each 2-week period

Dates (1939)	Tank No. 1			2			3			4			5			6		
	Min.	Ave.	Max.	Min.	Ave.	Max.	Min.	Ave.	Max.	Min.	Ave.	Max.	Min.	Ave.	Max.	Min.	Ave.	Max.
July 10-25	63.1	64.4	66.5	64.2	71.5	78.4	63.4	70.7	73.7	63.0	64.1	66.1	63.0	64.1	66.1	63.0	64.0	66.1
July 26-Aug. 8	66.7	67.5	68.4	69.5	70.3	71.1	71.3	72.9	73.9	66.5	67.2	68.2	66.3	67.1	68.2	66.2	67.3	69.6
Aug. 9-22	64.6	66.1	67.6	69.2	70.1	70.7	72.0	72.7	73.4	[1]67.0	[1]71.6	[1]76.4	[2]64.6	[2]67.4	[2]70.7	[3]49.1	[3]52.4	[3]67.0
Aug. 23-Sept. 5	62.2	64.2	66.2	[4]65.3	[4]69.7	[4]71.0	[4]66.1	[4]72.3	[4]73.8	68.3	70.5	73.2	65.6	67.3	69.7	49.0	49.3	49.8
Sept. 6-19	61.2	61.9	62.6	61.2	61.9	62.6	61.2	61.9	62.6	64.0	67.3	70.9	59.8	63.1	67.5	48.8	49.2	49.7
Sept. 20-Oct. 3	58.7	60.8	62.0	58.7	60.8	62.0	58.7	60.8	62.0	60.3	63.0	66.0	54.8	58.3	61.9	48.5	48.9	49.4
Oct. 4-17	58.5	60.1	61.0	58.5	60.1	61.0	58.5	60.1	61.0	60.0	61.8	63.6	54.7	57.1	58.7	48.4	48.7	49.2
Oct. 18-31	57.3	58.8	60.3	57.3	58.8	60.3	57.3	58.8	60.3	53.8	56.1	58.7	48.6	51.1	53.8	47.7	48.5	49.3
Nov. 1-14	55.2	56.0	57.1	55.2	56.0	57.1	55.2	56.0	57.1	48.6	51.6	54.8	44.3	46.9	49.8	48.2	48.7	49.4
Nov. 15-28	53.7	54.7	55.7	53.7	54.7	55.7	53.7	54.7	55.7	46.0	48.1	49.8	41.0	42.7	46.6	48.4	48.9	49.4
Nov. 29-Dec. 12	52.8	53.5	54.0	52.8	53.5	54.0	52.8	53.5	54.0	43.0	44.8	46.5	38.0	39.7	41.6	48.3	48.5	49.0

[1]Changed August 10 to conform to the surface temperature of Skaha Lake, British Columbia.

[2]Changed August 10 to conform to a temperature 5° F. below the surface temperature of Skaha Lake.

[3]Changed August 10 to conform to the temperature of Skaha Lake just below the thermocline.

[4]The temperature in Tanks Nos. 2 and 3 was lowered to city water temperature (the same as that of No. 1).

Toward the end of the experimental period the temperatures in this tank (No. 5) fell as low as 38.0° F. These low temperatures greatly reduced the food consumption, and rate of growth of the fish. The mortality rate of the fish in this lot was increased by the low water temperatures while the utilization of food (efficiency factor) declined sharply.

The fish in Tank No. 6 were retained in water of varying temperatures, approximately the same as those in Tanks No. 1, 4, and 5, until August 11, at which time the water temperatures were lowered to 48°-50° F. to correspond to the temperature in the layer of water just below the thermocline of Skaha Lake. This temperature of the upper hypolimnion was maintained in the tank (No. 6) until the end of the experimental period.

The water temperature of the layer just below the thermocline, when reproduced in the experimental tanks, proved to be much superior to any of the other temperatures used in producing growth of young sockeye salmon fingerlings. Not only did the growth rate exceed that of the others lots, but the utilization of food and its conversion into fish flesh was the best of the group of experimental lots. During the entire experimental time the fish in the No. 6 tank did not suffer a single mortality.

The results of this experimental study are quite in line with the findings of those individuals who have studied the young sockeye salmon during their residential period in lakes.

Ricker (1937b), in his study of the fish in Cultus Lake, British Columbia, wrote on page 450:

> "The summer feeding of fingerlings appears to be chiefly confined to the region between 5 and 15 metres depth, which includes the thermocline and adjacent narrow strips of the epilimnion and hypolimnion. Foraging is limited upward by scarcity of food, and downward by poor illumination or low temperature."

For the three years of observation Ricker (1937a) recorded the temperature of the 15 meter depth strata as varying from a low of 6.06° C. (42.91° F.) to a high of 14.68° C. (58.42° F.) for the period from July to November.

Ward (1927, 1929) observed the movements of young sockeye salmon in lakes and indicated that the young fish left the warm surface layer during the warm summer months.

In conducting the ecological survey for the Grand Coulee fish-salvage program, Chapman[1] found the young sockeye salmon in Lakes Wenatchee, Palmer, and Osoyoos were in the zone of cool water near the thermocline during the months of August and September. The warm surface layers of the lakes were devoid of young sockeye as were the depths of the lakes sampled.

From the experimental evidence and field observations, it would appear that the young sockeye salmon are very selective in their choice of water of uniform temperature, choosing that water near the thermocline in preference to warmer surface water or colder waters in the depths of the lakes.

[1]Chapman, Wilbert M. Unpublished data. State of Washington Department of Fisheries.

Summary and Conclusions

1. Six experimental tanks each containing an initial number of one hundred sockeye fingerlings were used in an experimental study of the effects of water temperatures on the growth, food utilization, and mortality of the young fish.

2. The young sockeye salmon fingerlings were not able to tolerate water temperatures as high as 78° F. for more than a few days. At water temperatures of 70° F. the fish were able merely to maintain themselves. (Tank No. 2.)

3. At water temperatures of 73° F. the sockeye salmon fingerlings lost weight and experienced considerable mortality. Reducing the water temperature (to 62°-53° F. range) improved the rate of growth and utilization of food. (Tank No. 3.)

4. The surface water temperatures of Skaha Lake during late summer are too warm for successful rearing of young sockeye salmon. During the fall months the decline in temperature of the surface water makes it again acceptable to the young salmon. (Tank No. 4.)

5. Water temperatures that average 5° F. less than the surface water temperature of Skaha Lake proved to be much better than the surface water temperatures during the time of the experiments. Water temperature in the range of approximately 45° F. to 39° F., however, produced poor growth with low food conversions in experimentally reared sockeye salmon. (Tank No. 5.)

6. The water temperatures as found in the upper layers of the hypolimnion of Skaha Lake during the summer and fall months proved optimum for the rearing of sockeye salmon fingerlings. (Tank No. 6.)

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Discussion

Dr. Ricker: I wish to mention in confirmation of what Dr. Donaldson has said that at one time Dr. R. E. Foerster maintained some fingerling sockeye salmon in the surface water of Cultus Lake by making a floating cage trap—the idea being, of course, to see whether this would be a possible way of rearing them and protecting them from their enemies. However, he found, as Dr. Donaldson and Mr. Foster did, that the cage was unsuitable for the young sockeye salmon; that they lost weight and there was a high mortality, even though they were artificially fed for a while, presumably because of the high temperature.

TREATMENT OF POTTER'S LAKE, NEW BRUNSWICK, WITH ROTENONE[1]

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ABSTRACT

Potter's Lake, of 113 acres surface area, was treated with 1,100 pounds of derris powder containing 5 per cent rotenone on July 24, 1939. The resulting concentration, if even distribution was secured, was slightly in excess of 0.5 p.p.m. derris, or 0.025 p.p.m. rotenone. The distribution was made by placing the derris powder in coarse gunny sacks and towing these behind row boats. The powder forms a cake in water and a gentle kneading of the sacks was required to insure proper dispersion. Algae, rooted aquatic vegetation, rotifers, Hydracarina and most immature aquatic insects survived. Planktonic microcrustaceans, *Chaoborus* larvae, a snail, *Campeloma decisum*, and one species of leech were killed.

The microcrustaceans and *Chaoborus* larvae were again plentiful in the spring of 1940. About 25,700 fish, large and small, were killed. The following species were involved: *Anguilla rostrata, Catostomus commersonnii, Ameiurus nebulosus, Esox niger, Micropterus dolomieu, Lepomis gibbosus, Morone americana* and *Perca flavescens*. A few fry of *Catostomus, Esox* and *Perca* were present in the lake in 1940, indicating an upward migration around a barrier in the outlet at flood time or a survival in the lake.

INTRODUCTION

The use of rotenone in fresh-water fishery management for the control and destruction of unwanted fish is receiving ever-increasing attention. Since its use in this manner is a comparatively recent innovation, much information is still to be secured on the drug's action, not only upon fish, but also upon fish-food organisms, particularly when applied in practical experiments in nature. Information of this character was obtained at Potter's Lake. The treatment of this lake with rotenone, in an endeavor to destroy the existing fish population, constituted an integral part of a program designed to rehabilitate the lake as a trout habitate. However, the purpose of this article is not to report upon the program as a whole, but rather to deal more specifically with the action of rotenone upon aquatic life present in the lake.

THE LAKE

Potter's Lake is a head-water lake whose outlet, by way of the Moannes Stream, flows into the St. Croix River, which forms part of the international boundary between the Province of New Brunswick and the State of Maine. The lake is roughly circular in shape. From a survey made over the ice, the area was determined as 113 acres and

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the volume as 34,600,000 cubic feet. The maximum depth was 29.5 feet (9.0 meters). The water over about 60 per cent of the area was less than 6 feet in depth. There is one small inlet draining a cedar swamp.

The Character of the Water

Although observations have been made for some time and at all seasons of the year upon the physical and chemical conditions of the water in Potter's Lake, it will serve the purpose of this paper if only certain data, secured near the time of the treatment, are recorded.

The lake was treated with rotenone on July 24, 1939. No hydrographic observations were made on that date, but the temperature for each meter level was secured in the deeper part of the lake on July 26. At the same location, the temperature, dissolved oxygen content and pH value of the water were determined at various depths on July 11 and August 1. On the former date, the dissolved carbon dioxide content was determined, in addition. These data are presented in Table 1. The blank places in the table signify that no observation was made.

Table 1.—Temperature, dissolved oxygen and carbon dioxide content in millimeters per liter, and pH value of the waters of Potter's Lake, 1939

Depth (meters)	Temperature, ° C.			Dissolved O_2		Dissolved CO_2	pH[1]	
	July 11	July 26	Aug. 1	July 11	Aug. 1	July 11	July 11	Aug. 1
0	25.4	27.6	23.4	5.34	5.51	1.1	6.8	6.7
1	.....	27.3	23.3	.....	.....	....	....	....
2	25.0	22.5	23.3	5.37	5.54	2.0	6.7	....
3	.....	20.6	23.2	.....	5.45	....	....	....
4	18.9	18.6	18.7	5.23	5.09	1.8	6.7	....
5	.....	15.6	16.0	.....	4.76	....	....	....
6	14.8	13.0	13.4	4.64	4.16	1.9	6.4	....
7	.....	11.9	12.0	.....	3.21	....	....	....
8.5	10.4	11.4	11.6	3.35	1.22	3.8	6.0	5.9

[1]Brom cresol purple colorimetric scale.

It has been shown that increased temperature greatly increases the toxic action of rotenone upon fish (Leonard, 1939; Smith, 1940). Leonard (1939) also found that rotenone in derris powder was more lethal to certain species of fish in acid than in alkaline water. This difference in the action of rotenone in reference to the acidity of the water was more apparent when dealing with the hardy goldfish than with the less resistant golden shiner and brook stickleback. This author's data illustrate further that the golden shiner and brook stickleback lost their equilibrium, when exposed to rotenone, somewhat sooner in unaerated than in aerated water, although the average time of death of the fish in the two types of water showed no consistent difference. Obviously, knowledge upon those aquatic factors which may affect the solubility of rotenone or the respiratory activity of fish is important.

In the deeper stratified portion of Potter's Lake there were marked differences in the hydrographic conditions between the surface and

bottom waters (Table 1). On July 26, 1939, the surface water had a temperature of 27.6° C., while that at the bottom, a depth of 8.5 meters (27.9 feet), was 11.4° C. On July 11, the dissolved oxygen content was 5.34 milliliters per liter and the pH value was 6.8 at the surface, and 3.35 milliliters and 6.0, respectively, at the bottom. Thus the speed of the toxic action of the rotenone varied considerably in the various strata of water. It was noted that when once under the influence of the poison, fish tended to come to the surface and there to move in a violent and irregular manner, often breaking water. An upward movement of fish into warmer water would hasten their death. A few fish were still dying on the day following the application of the rotenone and these may have been individuals which had remained in deeper and cooler water. It is improbable, however, that many, if any, fish were present in the coolest, but oxygen-deficient, bottom water found in the deepest areas of the lake.

The Treatment

Derris powder, containing 5 per cent rotenone, was used. A concentration of 0.5 p.p.m. derris with the above strength of rotenone has been found lethal for a number of fresh-water fish (Leonard, 1939; Smith, 1940). Lower concentrations may kill fish, but under some circumstances they may prove ineffective. Accordingly, 0.5 p.p.m. derris or 0.025 p.p.m. rotenone was the concentration planned for Potter's Lake. Actually, 1,100 pounds of derris powder was used, which gave a concentration slightly greater than planned.

The poison was put into Potter's Lake on July 24, 1939, a day with little wind, notwithstanding the desirability of a wind to hasten the mixing of the drug in the water. The distribution was made by placing the derris powder in coarse gunny sacks and then towing these behind row boats. Since the powder forms a cake when submerged in water it was necessary to gently knead the material to secure a proper mixing or suspension in the water.

Other methods have been employed, apparently with success. Eschmeyer (1937, 1938, 1939) poured the powder in the wake of an outboard motor or broadcasted it over the surface by hand. In some instances, he expedited the mixing in deep water with dynamite. Hagen (1940) made a concentrated mixture of the powder in water and then sprayed this over the surface.

With four boats, and two men to each boat, the distribution of the powder in Potter's Lake required 5 hours.

It was impossible to determine how well the drug was distributed throughout the volume of the lake. The writer is not aware of a method sufficiently delicate to demonstrate the presence of rotenone in concentrations as low as 0.025 p.p.m. To compensate for the greater volume of water in the deep portions of the lake the boats were rowed more slowly over those areas, and in the deepest water

100 pounds of derris were distributed at a depth of 15 to 20 feet by weighting the sacks. (Small stones were placed in the sacks, not only to weight them, but also, by moving the sacks up and down, to prevent the derris powder from forming a cake.)

The Effect Upon Aquatic Life

Algae and rooted aquatic vegetation.—There was no evidence that rotenone acted upon the plant life of the lake. Species of algae, belonging to the genera *Aphanocapsa, Anabaena, Dinobryon, Staurastrum, Tabellaria* and others, common to the phytoplankton of Potter's Lake, were plentiful before and after the rotenone was added to the water.

Zooplankton.—*Vorticella* sp., attached to filaments of *Anabaena,* survived the treatment. Of the rotifers in the plankton, *Asplanchna, Keratella, Polyarthra, Notholca, Conochilus,* and possibly others, were present in the plankton hauls taken a short time after the poisoning. In fact, there were no observations to indicate that these forms had been harmed. *Hydracarina* also survived.

Fifteen-minute plankton tows, non-quantitative but of value for comparison, were taken with a No. 5 plankton net before and after the rotenone was added to the water. These samples were diluted to 450 milliliters and counts of the zooplankters made. The results are shown in Table 2, in which the data represent the numbers of each species in an average milliliter of the diluted samples. Insofar as these tows sampled the zooplankton in the lake, they showed that the planktonic microcrustaceans were largely killed by the rotenone. Nevertheless, the tows also showed that certain numbers of cladocerans and copepods survived and were able to repopulate the lake. The repopulation was not appreciable, however, until the following spring (1940). These observations agree with similar evidence from the treatment of other fresh-water lakes with rotenone (Smith, 1940).

More comprehensive information upon the return of the microcrustaceans can be gained by comparing quantitative samples secured on June 2, 1939, with others taken on May 30, 1940 (Table 3). These samples were taken at meter intervals in the deep water of the lake with a Foerst plankton trap of 10 liters capacity. The dominant cladocerans and copepods (*Holopedium, Daphnia, Bosmina, Diaptomus, Cyclops*) of the plankton of Potter's Lake were well represented in 1940, and in some instances better than in 1939.

Bottom fauna.—The bottom organisms were sampled with an Ekman dredge to detect, if possible, any mortality among them. In Table 4, the numbers taken on May 26 to June 1, 1939, and on July 13 to 17, 1939, before the waters were treated, may be contrasted with those secured on August 3 and 4, 1939, and on May 27 and 28, 1940, after the rotenone was put into the lake. The same 10 stations were sampled at each period.

Table 2.—Comparative counts of microcrustacea in Potter's Lake

[The plus signs indicate counts less than one. All samples except that for July 24, 1939, were taken after treatment with rotenone.]

Date	*Diaphanosoma*	*Holopedium*	*Daphnia*	*Ceriodaphnia*	*Bosmina*	*Chydorus*	*Polyphemus*	*Leptodora*	*Epischura*	*Diaptomus*	*Cyclops*
(1939)											
July 24	....	263	....	....	+	....	....	+	....	2	23
August 3	....	....	....	....	....	....	....	....	....	....	....
September 5	....	....	....	....	....	....	....	....	....	....	....
October 4	....	....	+	....	....	....	....	....	....	....	....
(1940)							....	....			26
May 14	....	30	2	....	5	+	....	....	....	+	
May 30	+	351	16	1	22	....			1	29	2
June 14	6	23	960	3	1	....	5	7	10	67	5
July 2	....	....	290	....	....	....	....	1	2	110	3

Table 3.—Numbers of zooplankters in plankton-trap samples from Potter's Lake, June 2, 1939, and May 30, 1940

[Number per ten liters]

Depth in meters	Year	Cladocera	Copepoda	Copepod metanauplii	Rotatoria
0	1939	76	55	60	173
0	1940	356	28	12	156
1	1939	126	58	71	258
1	1940	421	40	22	540
2	1939	148	60	59	246
2	1940	251	19	23	230
3	1939	112	37	42	180
3	1940	55	17	45	932
4	1939	74	55	50	158
4	1940	25	7	17	2,343
5	1939	36	450	62	83
5	1940	6	2	20	5,853
6	1939	20	515	70	37
6	1940	3	2	52	7,579
7	1939	1	415	99	315
7	1940	7	0	103	16,073
8	1939	0	666	36	820
8	1940	0	11	117	24,988

For the most part, the worms, crustaceans, immature insects and mollusks that comprised the bottom fauna of Potter's Lake showed no significant diminution in numbers which could definitely be ascribed to the action of rotenone. These observations corroborate the findings of Leonard (1939) and Smith (1940). Nevertheless, although it is not particularly apparent from Table 4, some unexpected mortalities occurred. *Chaoburus* larvae, which may be classed either as bottom or plankton organisms, were killed in large numbers, as became evident when they floated to the surface and drifted into the shores.

Their presence in bottom and plankton samples after the treatment showed that the *Chaoborus* population had not been entirely destroyed. The snail, *Campeloma decisum,* was also killed, but unlike *Chaoborus,* no living specimens have since been observed. In addition, a leech, as yet unidentified, was destroyed in numbers.

Table 4.—Numbers of bottom organisms from Potter's Lake, based on dredge hauls from 10 stations

Organism	Totals for 20 hauls of Ekman dredge			
	May 26-June 1, 1939	July 13-17, 1939	August 3-4, 1939	May 27-28, 1940
Oligochaeta	25	16	8	1
Hirudinea	6	4	0	3
Hyalella knickerbockeri	479	612	903	566
Sialidae	1	0	2	1
Ephemeridae	10	3	0	7
Anisoptera	1	2	0	3
Zygoptera	3	1	0	2
Trichoptera	20	10	3	5
Chironomidae	49	44	53	61
Chaoborus larvae	188	6	1	38
Chaoborus pupae	0	6	0	1
Hydracarina	0	3	2	0
Sphaeriidae	49	71	143	99
Gastropoda	22	35	27	56
Totals	853	813	1,142	843

Rotenone is used commercially in insecticides. In view of this it is interesting, as well as pertinent to find that the drug when in aqueous solution has little deleterious action upon immature aquatic insects. Adult aquatic beetles and bugs also appear immune. The apparently unpredictable action of rotenone, as here shown by its lethal effects upon *Chaoborus* and not, so far as known, upon other aquatic insect larvae and pupae, has similarly been encountered in its use for the control of terrestial insects. It has been found highly effective against some pests, while against others wholly ineffective (Roark, 1933).[2]

Fish.—The following species of fish were killed by rotenone in Potter's Lake:

Anguilla rostrata—Eel
Catostomus commersonnii—Common sucker
Ameiurus nebulosus—Brown bullhead
Esox niger—Eastern pickerel
Micropterus dolomieu—Smallmouth black bass
Lepomis gibbosus—Common sunfish
Morone americana—White perch
Perca flavescens—Yellow perch

[2]It should be noted, however, that insecticidal concentrations are always much higher than those employed against fish; also that for insecticidal use the rotenone is dissolved in some solvent or used in dusting powders. (Its solubility in water is about 1 p.p.m.).

The number of fish in the lake and the number per acre, as determined from direct counts and estimations, are given in Table 5. Bullheads, pickerel and yellow perch fry or fingerlings, and smallmouth black bass yearlings, were counted along an extent of 12.8 per cent of the shoreline, and from this count an estimation of about 18,600 young fish was made for the entire lake. All the older fish were counted individually, and the number of these was 7,087. Thus, the total number of fish, large and small, killed by the rotenone in Potter's Lake was about 25,700. Material and data are at hand for a future and more detailed analysis of the fish population.

Table 5.—Number of fish killed in Potter's Lake by rotenone

Genus	Number in lake	Number per acre
	Number of young fish estimated from counts made on several sections of the shoreline	
Ameiurus (fry)	7,879	69.1
Esox (fry)	1,873	16.4
Micropterus (yearlings)	1,806	15.8
Perca (fry)	7,084	62.1
Total	18,642	163.4
	Number of older fish from direct counts	
Anguilla	2,368	20.8
Catostomus	207	1.8
Ameiurus	763	6.7
Esox	817	7.2
Micropterus	446	3.9
Eupomotis	888	7.7
Morone	27	0.2
Perca	1,571	13.8
Total	7,087	62.1
Grand total	25,729	225.5

Fish were dying before the distribution of the derris powder was completed. A large number of fish came to the surface or into shallow water at the shore when they were in distress and as they died. Practically all that were killed and immediately sank to the bottom away from the shore came to the surface within three days. For instance, on the fourth day only 57 of the above total of older fish were collected. The eels remained on the bottom for the longest period, and together with suckers were the most resistant to the poison. Eschmeyer (1939) recorded that small fish tended to die first, and were taken by larger predators before the latter were distressed by the action of rotenone. Our experience was that the young and old of any one species were similarly affected, but, as noted, certain species resisted the poison for a longer time.

No fry or fingerlings of the eel, sucker, black bass, sunfish or white perch were collected for the above estimation of the number of small fish in the lake. It appeared that the young of the smallmouth black bass and sunfish had not risen from the nests before the rotenone was put into the water. Recently-hatched sunfish were found dead in a number of nests. Leonard (1939) observed that 0.50 p.p.m. derris (5 per cent rotenone) did not kill eyed brown trout eggs, but that the fry succumbed as soon as they began to hatch. It is possible, there-

fore, that unhatched eggs (none were observed) survived in Potter's Lake, although the rotenone probably remained lethal sufficiently long to destroy any fry upon emergence.

Eighteen days (August 11, 1939) after the lake was treated, 45 killifish (*Fundulus diaphanus*) were placed in wire cages in Potter's Lake. After 24 hours, 36 of the 45 were dead and the remainder in distress. A similar test was made on September 7 with killifish, lake chubs (*Couesius plumbeus*) and suckers (*Catostomus commersonnii*). Although some of these fish died shortly after they were introduced into the cages, it is believed the handling that they received was responsible for the deaths, rather than a persistent toxic action of the rotenone, for the fish did not react as under the influence of rotenone, and the greater number were normal on the following day.

In a small lake which had received 1.33 p.p.m. derris (5 per cent rotenone), Smith (1940) found that the toxicity of the drug toward fish was dissipated within a month at summer temperatures. Leonard (1939) stated that a 1 per cent suspension of derris powder containing 5 per cent rotenone lost from 60 to 75 per cent of its toxicity in 34 days. The quite rapid decline and disappearance of the toxicity of rotenone toward fish permits, without undue delay, the stocking of other species. In this regard rotenone has much advantage over other fish poisons, such as copper sulphate.

Gill nets were set in the lake during September, 1939, but no fish were captured. However, in the spring and early summer of 1940, fry of the sucker (identified by Dr. Carl L. Hubbs), pickerel and yellow perch were present in the lake. A barrier was erected in the outlet to prevent the upward migration of fish, but a short period of flooding around the barrier in early spring may have permitted early spawners to penetrate into the waters above. An alternative explanation for the presence of the fry, and perhaps a more likely one, is that a certain number of fish survived the treatment with rotenone.

Potter's Lake was stocked with trout fingerlings (*Salvelinus fontinalis*) in June, 1940. In order to gauge the success of the stocking, the lake will again be treated with rotenone, in 1941. This procedure will probably reveal how many fish either re-entered the lake or escaped the first poisoning, and how extensive was their propagation.

Summary

1. Potter's Lake, with an area of 113 acres and a volume of 34,600,000 cubic feet, was treated with 1,100 pounds of derris powder, containing 5 per cent rotenone, on July 24, 1939. The resulting concentration, if the distribution was even, was slightly in excess of 0.5 p.p.m. derris or 0.025 p.p.m. rotenone.

2. The temperature, dissolved oxygen and carbon dioxide content and pH value of the water for dates near the time of the treatment are given.

3. The derris was distributed by towing the powder in coarse gunny sacks behind rowboats. The powder forms a cake in water and a

gentle kneading of the sacks was necessary to insure proper dispersion.

4. Algae, rooted aquatic vegetation, rotifers, Hydracarina, and worms, crustaceans, immature insects and mollusks of the bottom fauna were, with few exceptions, unaffected by the rotenone.

5. Planktonic microcrustaceans, *Chaoborus* larvae, a snail, *Campeloma decisum*, and a species of leech were killed. Sufficient numbers of microcrustaceans and *Chaoborus* survived to repopulate the waters of the lake.

6. An estimated total of about 25,700 fish, large and small, were killed. *Anguilla rostrata, Catostomus commersonnii, Ameiurus nebulosus, Esox niger, Micropterus dolomieu, Lepomis gibbosus, Morone americana* and *Perca flavescens* comprised the fish population.

7. *Catostomus, Esox* and *Perca* fry were found in the lake in 1940, indicating either an upward migration around a barrier in the outlet at flood time or a survival in the lake.

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Discussion

Mr. John Greenbank: Is it not possible that instead of suckers showing up well because they had more resistance to rotenone, they merely took longer to get down to where the rotenone was? It has been shown in experiments that the sucker is much less resistant than many other fishes.

Dr. Smith: That is perhaps only partial evidence. I made that statement because in some tests made under control conditions, a similar situation obtained, and it corroborated what had been found in the lake itself.

Mr. G. C. Toner: May I ask Dr. Smith whether this substance has been used in stream surveys or for purposes of determining ichthyological distributions?

Dr. Smith: Not directly for that purpose. We have used it in an attempt to clear the population of fish from a stream as well as from lakes, but not directly to collect fish.

Mr. Greenbank: It has been made use of for such purposes in recent years. Hubbs used it in several of his collecting expeditions during the last two summers. Schultz, who reported at the meetings this week of the American Society of Ichthyologists and Herpetologists, used it in collecting fishes and other specimens in the Phoenix and Samoan Islands in 1939, and had remarkably good success with it.

FOOD OF GARS IN TEXAS

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ABSTRACT

The study was initiated to help answer the question raised by sportsmen and conservationists of whether or not gars are detrimental to fishing in Texas. Some of the literature on the food of gar is reviewed. Tables show where and when the Texas specimens were taken, and what food those from each locality contained. Of 21 large alligator gars, *Lepisosteus spatula*, 18 were empty. Three contained clues to having eaten an eel, as well as *Aplodinotus grunniens* and *Ictiobus bubalus*. Examinations of 28 spotted gars, *Lepisosteus productus*, showed crayfish, *Dorosoma cepedianum*, sunfish and minnows not over 40 millimeters long, and *Palaemonetes exilipes* to be present in that order of importance. Only 7 were empty. Longnose gars, *Lepisosteus osseus*, numbered 297, of which 115 were empty. Food was *Moxostoma congestum*, *Mugil* sp., *Dorosoma cepedianum*, sunfish, catfish, and crayfish. None of the black basses was found in stomachs of any one of the three species of gars.

INTRODUCTION

There has been a popular belief that gars are an important factor in impairing the fishing in the fresh waters of Texas. So strong were some of the accusations and circumstantial evidence against gars that the most direct possible check on their food habits seemed to be called for. It was desirable to examine numbers of stomachs, preferably from localities where sport fishing for largemouth and spotted bass was conducted and where the gars were being eradicated in predatory-fish control campaigns.

Students in the Department of Fish and Game at the Agricultural and Mechanical College of Texas, as a part of their field training, seined, examined some of the stomachs, and helped materially in making significant the number of specimens reported upon. The Texas Game, Fish and Oyster Commission cooperated by supplying transportation in Kerr County and the services of personnel. Camping facilities and other aid were furnished by the Kerr County Wildlife Association. The Texas Cooperative Wildlife Unit helped provide equipment.

There has been no previous publication on the food of gars in Texas. Literature on the subject covering other parts of central and eastern United States begins as early as the quotation by Goode (1884, p. 664) of Champlain's description in the year 1609 of the longnose gar at the lake that bears his name. The Indians said that the gar lay at the surface with jaws agape, and caught birds alighting on the limb-like jaws. Goode then stated that, although it is reputed to be destructive to the young of other fish, the longnose gar rarely has fish in its stomach. Goode also quoted a Mr. Stearns who said that

"*Lepidosteus spatula*" preys on all smaller fishes. Forbes (1888) examined six "*Lepidosteus platystomus*" and "*L. osseus*" that had eaten only "hickory shad (*Dorosoma*), black bass (*Micropterus*), and some minnows (Cyprinidae)." Marshall and Gilbert in 1905 reported one *Lepisosteus osseus* as empty. In 1913, Richardson stated that a 16-day-old *Lepisosteus platostomus* ¾-inch long contained 17 large *Scapholeberis mucronata*. Ten specimens of *Lepisosteus osseus* were reported by Pearse (1918) to contain about 89 per cent fish, 10 per cent insect larvae, and 1 per cent adult insects. Data on two species of gars from Lake Maxinkuckee (Evermann and Clark 1920) are for *Lepisosteus osseus*: "Small fishes were frequently found in their stomachs, but not to the extent that popular belief would indicate . . . ." and for *Lepisosteus platostomus*: ". . . . this species feeds chiefly upon small fishes, ..." In Illinois (Forbes and Richardson, 1920), for *Lepisosteus osseus*, the food encountered was 11 minnows from the stomach of a male 24 inches long, 16 minnows from the stomach of a 27-inch specimen, and 16 minnows from a 2-inch specimen. No yellow perch or sunfish were found. Two *Lepisosteus osseus*, average length 278 millimeters, from Lake Mendota (Pearse, 1921) contained only fish. DeRyke and Scott (1922) found two snails in a *Lepisosteus osseus* 542 millimeters long. Potter's (1924) paper recorded 10 "*Lepidosteus platystomus*" from Lake Okoboji to have contained 60 per cent fish and 40 per cent crayfish. Recently (Scott, 1938) examined 89 "*Lepidosteus*" in Indiana (species not stated). Fifty were empty, 18 contained fish remains, 1 contained a mammal, 1 a fragment of crayfish carapace, and 19 contained identifiable fish numbering as follows: 11 yellow perch (*Perca flavescens*), 2 black bass (*Micropterus*), 6 brook silversides (*Labidesthes*), 2 pickerel (*Esox*), 1 rock bass (*Ambloplites*), and 1 crappie (*Pomoxis*).

The Texas material analyzed in Tables 1, 2, and 3, was obtained from gars that had been seined, with the exception of those from Jefferson County, which were taken with set nets. Game Warden Delbert Conner obtained the latter from a commercial fisherman and submitted the stomach contents for identification.

In each table the data for the species are arranged according to the river system from which the fish came. In the following paragraphs the various foods will be mentioned in the order of their importance.

The large proportion of empty stomachs, 18 of 21 of the alligator gars, may be explained by the long period of time that the fish were in the net. Sixteen were in a set net for an unknown time, possibly overnight. Five were taken by long hauls with a 500-foot seine. Probably some food was lost by regurgitation, a common occurrence with this species, according to commercial netters. The large amount of plankton in the specimen from Wickson Lake is assumed to have been within the digestive tract of a large *Ictiobus bubalus*, because more of this species was caught at the time than of any other plankton-feeding

Table 1.—Food of alligator gars (Lepisosteus spatula *Lacépède*) *in Texas*

River System	County	Lake or stream	Date	Standard length (millimeters)	Number specimens	Number empty	Food		
							Organisms	Number	Length[1] (millimeters)
Neches	Jefferson	Neches River	Jan. 1, 1940	640-1,440	16	15	vertebral column of eel	1	300
Brazos	Madison	Twin Lake	Sept. 11, 1939	1,070	1	0	otoliths of *Aplodinotus grunniens* (?)	2	....
							scales of *Ictiobus* sp.		
Brazos	Brazos	Wickson Lake	Sept. 4, 1939	1,070-1,270	4	3	plankton (100 cubic centimeters of ostracods, cladocera, and *Chaoborus* larvae)	....	....

[1]Standard lengths of fish.

Table 2.—Food of spotted gars (Lepisosteus productus *Cope*) *in Texas*

River system	County	Stream or lake	Date	Standard length (millimeters)	Number specimens	Number empty	Food		
							Organisms	Number	Length (millimeters)
San Jacinto	Walker	West fork, San Jacinto River	July 17, 1940	143	1	0	*Gambusia affinis*	1	20
San Jacinto	Montgomery	Lake Creek	June 20, 1940	105	1	0	*Gambusia affinis*	1	25
Brazos	Brazos	.....	1939	192	1	0	*Palaemonetes*	1	25
Brazos	Brazos	Peach Creek	Oct. 20, 1939	138-141	2	1	*Palaemonetes*	1	20
Brazos	Brazos	Peach Creek	April 3, 1940	217	1	0	*Palaemonetes* (crayfish)	1	25
								1	20
Brazos	Brazos	Peach Creek	June 19, 1940	64-132	2	0	*Chaenobryttus gulosus*	2	15-19
							Gambusia affinis	2	17-35
							Palaemonetes	1	25
							Chaoborus larvae	2	
							Copepods	3	
							Amphipod	1	
Brazos	Brazos	Tonkaway Lake	June 25, 1940	90	1	0	*Chaenobryttus gulosus*	1	21
							Spirogyra, trace		
Brazos	Brazos	Green Lake	July 11, 1940	141-156	2	0	*Fundulus dispar*	1	27
							Sunfish	1	23
							Palaemonetes	1	25
Brazos	Grimes	Pond, by Navasota River	June 10, 1940	100	1	0	*Notemigonus crysoleucas*	1	40
Brazos	Grimes	Navasota River	Nov. 5, 1939	300	1	1	.....	....	....
Brazos	Madison	Twin Lake	Sept. 11, 1939	330-700	8	5	*Dorosoma cepedianum*	2	70
							Fish	1	25
							Corixa	1	5
Brazos	Robertson	Gifford-Hill (gravel pit)	June 28, 1940	340	1	0	Fish	1	35
							Beetle	1	25
							Palaemonetes	1	25
San Bernard	Wharton	San Bernard River	May 12, 1940	470-540	5	1	*Notropis lutrensis*	1	40
							Fish	2	30
							Crayfish	4	50-100
Colorado	Colorado	Eagle Lake	Oct., 1938	260	1	0	Sunfish	6	15-38
							Palaemonetes	54	14-28

Table 3.—Food of longnose gars (Lepisosteus osseus *Linnaeus*) *in Texas*

River system	County	Lake or stream	Date	Standard length (millimeters)	Number specimens	Number empty	Food		
							Organisms	Number	Length (millimeters)
Neches	Jefferson	Neches River	Jan. 31, 1940	1,050-1,200	5	0	*Dorosoma cepedianum*	7	60-190
							Mugil sp.	3	120-200
Brazos	Brazos	Wickson Lake	Sept. 4, 1939	380-800	16	7	*Dorosoma cepedianum*	4	65-150
							Sunfish	1	20
							Unidentified fish	8	20-60
							Notonecta	1	10
Brazos	Brazos	Wickson Lake	July 12, 1940	150	1	0	*Gambusia affinis*	1	27
Brazos	Brazos	Navasota River	Oct. 6, 1939	270-400	3	1	Centrarchid fish	1	16
							Fish	1	18
							Palaemonetes	1	25
Brazos	Brazos	Brazos River	June 15, 1940	530	1	1	.....	....	....
Guadalupe	Kerr	Guadalupe River	July 20 to Aug. 27, 1939	380-1,120	271	106	*Moxostoma congestum*	5	130-220
							Sunfishes	46	20-140
							Fish	62	16-120
							Dorosoma cepedianum	10	30-60
							Catfish	2	80-120
							Pomoxis annularis	1	60
							Crayfish	8	50-70
							Insects	25	15-70

fish, and their digestive tracts were filled with the same kind of plankton. Both *Ictiobus bubalus* and *Aplodinotus grunniens* were common in Twin Lake at the time the gars were taken. It is reasonable to deduce that these gars eat large, rough fish.

Relatively numerous collections (14) of the spotted gar gave a fair picture of its food habits. Crayfish and gizzard shad, *Dorosoma cepedianum,* were most important. Small sunfish and minnows not over 40 millimeters long came next. *Palaemonetes exilipes,* the fresh water shrimp, is a common item of diet.

Collections of longnose gars in six localities cover the greatest geographical range and have the greatest number of specimens. Most conspicuous is the sucker group, including a *Moxostoma congestum* about 9 inches long which was within one of the largest gars. Three good-sized mullets (*Mugil*) remained inside the fish from Jefferson County, indicating that the longnose gar does not regurgitate its food so easily as does the alligator gar when caught in a set-net. *Dorosoma cepedianum* appears prominently almost throughout the range. In numbers of specimens, the sunfishes are first, but, although one as large as 5½ inches occurred, the rest did not exceed 4, and most were 1 or 2 inches in standard length. Catfish were the second most abundant food item. Crayfish appeared commonly. Conspicuous by their absense were the smallmouth bass and spotted bass, the chief game fishes in Texas.

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CONTROL OF SPATTERDOCK (*NUPHAR ADVENA* AIT.) IN PONDS[1]

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ABSTRACT

Spatterdock (*Nuphar advena* Ait.) is an objectionable weed in southern ponds where its emergent leaves form a dense vegetation in which it is difficult or impossible to fish. Experiments dealing with the control of this plant were conducted in a pond in Central Alabama during the spring and summer, 1940. The results of these experiments are summarized briefly as follows: (1) Spatterdock was effectively controlled by cutting the leaves five times (May 15, June 4, June 21, July 2, and July 24). (2). Four cuttings (June 4, June 21, July 2, and July 24) effectively controlled the plant when commercial fertilizer was applied on the first cutting date. (3). Effective control was obtained by pulling the rootstocks on May 15, and allowing the plants to remain in the pond. (4). Death and decay of the rootstocks of spatterdock began toward the base and progressed to the apex. (5). Sprays consisting of mixtures of creosote and fuel oil, and sodium chlorate and sodium arsenite killed the leaves of spatterdock but did not injure the rootstocks.

INTRODUCTION

Fish culturists interested in pond improvement are confronted by three major problems: (1) Methods of enriching the water so that a large total weight of fish can be produced per acre; (2) methods of stocking such that legal size fish will constitute a large portion of the total weight of fish; and (3) the control of pondweeds.

This paper is the first of a series dealing with the control of the higher aquatic plants. It is concerned with the control of spatterdock and should be considered as a progress report since the experiments are being continued and expanded.

Spatterdock occurs in ponds and slow streams from Labrador and Nova Scotia westward to the Rocky Mountains and southward to Florida, Texas, and in Utah. It is an objectionable weed in ponds because its emergent leaves make fishing difficult or impossible.

GROWTH HABITS OF SPATTERDOCK

Spatterdock possesses a large, branching rootstock that grows on the pond floor to which it is attached by fleshy roots. The rootstocks may be as much as 4 inches in diameter and 6 feet or more in length (Figure 1). Numerous large, ovate-cordate, emergent leaves arise from the apical end of the rootstock. In an area dominated by the plant, its rootstocks form a mat strong enough to support a man, and its emergent leaves, standing 1 foot or more above the surface of the water, present a jungle in which it is difficult or impossible to fish (Figure 2).

[1]Published with the approval of the Director.

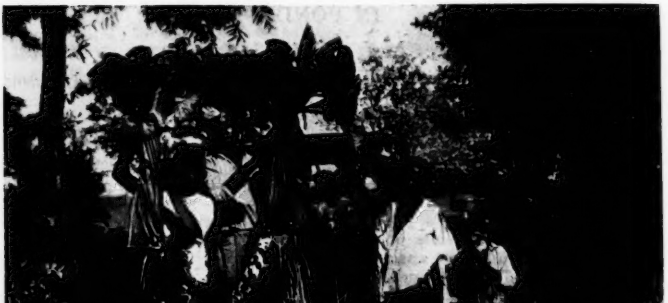

Figure 1.—Spatterdock plants. The two boys on the left are supporting a portion of a plant from the control plot. Note the large branching rootstock, a 4-foot section of which is lying on the ground, and clusters of leaves arising from the apices. The two boys on the right are holding plants from the cut plots, showing the progressive death and decay of the rootstocks.

The leaves die during the fall; new leaves begin to grow from the apex of the rootstock in early spring, but few are emergent before the first of April at the latitude of Auburn, Alabama. Great numbers of leaves are evident by the last of April, and the rootstock may increase 6 inches in length by the middle of May. The plant begins to bloom late in April or early in May, and although it continues to bloom throughout the summer, most of the flowers are produced in May and June. Rootstocks may increase 1 foot in length by the middle of the summer, but make little or no growth during the remainder of the season. Since rootstocks several feet long may be found, it is evident that the plant is a perennial.

Experimental Methods and Results

Mechanical treatments.—The mechanical treatments consisted of severing the leaves below the water surface on five plots and pulling the rootstocks on another. The plots, which were one-fortieth acre (33 by 33 feet) in area, were located in water that varied from 2½ to 5 feet in depth.

The leaves of spatterdock were cut below the water surface with a

scythe on Plots 1-5, inclusive. The rootstocks entering the plots were severed by cutting along the margins of each plot with a straight spade. This procedure was repeated each time the leaves were cut and was done to prevent food being translocated into the rootstocks from portions having intact leaves outside the plots.

The leaves were cut five times on Plot 1, the cutting dates being May 15, June 4, June 21, July 2, and July 24. They were cut four times on Plots 2, 3, 4, 5. The dates on which the leaves were cut were June 4, June 21, July 2, and July 24. In addition to cutting, Plot 2 received 20 pounds of commercial fertilizer (6-8-4, N-P-K) on June 4; Plot 3, 20 pounds of sodium nitrate; Plot 4, 20 pounds of superphosphate (16 per cent); and Plot 5, 20 pounds of ammophos (11 per cent N, 48 per cent P_2O_5). The fertilized plots were adjacent to each other; consequently, some of the fertilizer applied to one plot undoubtedly entered the other plots by wave action and diffusion.

On the second cutting date (June 4) on Plot 1, it was estimated that not more than 10 per cent as many leaves were present as on the uncut control. The rootstocks were about one-half as large on the cut plot as on the control, indicating that the plant was using food reserves in the formation of new leaves.

On June 21 (the third cutting date for Plot 1 and the second for Plots 2, 3, 4, 5), it was estimated that there was less than 5 per cent

Figure 2.—Right foreground: cut plots, showing decaying rootstocks floating on the surface, and the absence of leaves. Background and left foreground: control plots, showing the jungle of emergent leaves of spatterdock.

as many leaves on all cut plots as on the control; it was observed that there were fewer leaves on the fertilized plots than on the unfertilized plot. A typical rootstock from Plot 1 showed no evidence of new growth and had only one emergent leaf and one other beginning to grow. A rootstock from the uncut control, on the other hand, had increased about 1 foot in length, had 20 emergent leaves and three others commencing growth.

There were few leaves on the cut plots at the next cutting date, July 2. The rootstocks, which had formed a firm footing at the beginning of the experiment, no longer would support the weight of a man. It was found on examination that the rootstocks were decaying and only the apical 2 or 3 feet were alive. An extremely small number of leaves were found on the plots on July 24, and the rootstocks showed further evidence of decay.

There were three clusters of leaves on Plot 1 on August 28; these were cut. Plots 2, 3, and 4 were entirely free of leaves on this date; one cluster of spatterdock leaves was found near the boundary of Plot 5. Apparently, one rootstock had escaped severing at the boundary of the latter plot. Other than those mentioned, the entire rootstocks, including the apices, were dead and decaying on all plots. Many of the decaying rootstocks had broken loose and were floating on the surface of the pond (Figure 3).

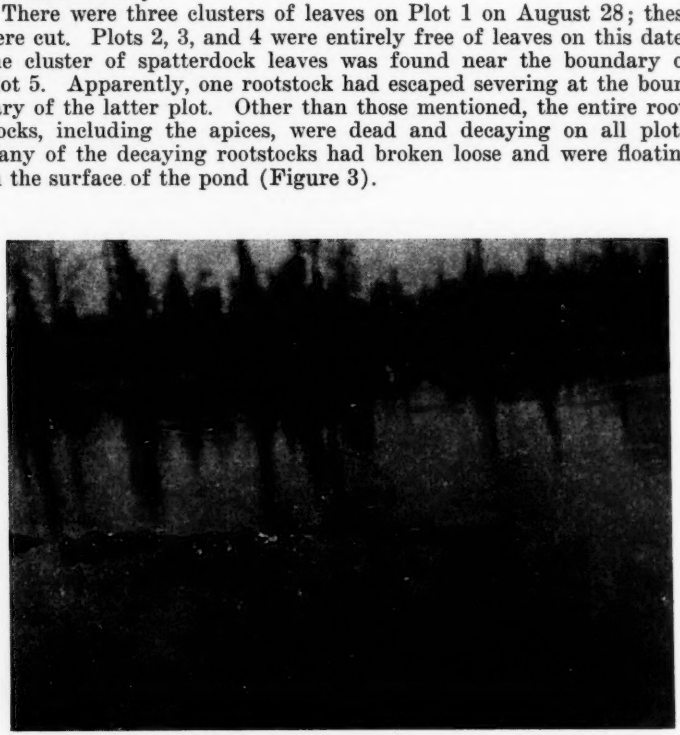

Figure 3.—Decaying rootstocks of spatterdock that have broken loose from the bottom of the pond and are floating on the surface.

On the date that the last observation was made, September 13, only two rootstocks were producing leaves on Plot 1; the leaves were removed. No leaves were present on Plots 2, 3, 4, and 5 (Figure 2). No firm rootstocks were found by wading in the plots on this date, and decaying rootstocks were continuing to break loose and float on the surface.

In Plot 6, the leaves were left intact and the rootstocks were pulled from the bottom of the pond on May 15. The spatterdock plants were allowed to remain on the plot, floating partly on the surface and partly submerged. A few weeks later, the rootstocks were found to be decaying, the decay beginning at the basal end and extending toward the apex. Most of the rootstocks disappeared during the summer and only one cluster of leaves was present on the plot on September 13.

Chemical treatments.—Three plots, each 20 by 20 feet, were located in the spatterdock-infested area of the pond on April 17. Plot 1 was sprayed with one-half gallon of a 1:9 mixture of coal tar creosote and fuel oil, Plot 2 with 1 gallon of the same mixture, and Plot 3 with 2 gallons of a solution containing 2 pounds each of sodium chlorate and sodium arsenite. On May 8, three additional plots (5 by 41 feet) were sprayed. Plot 4 received 1 gallon of the 1:9 mixture of creosote and fuel oil, Plot 5, 2 gallons of the same mixture, and Plot 6, 2 gallons of a solution containing 1 pound of sodium chlorate and 1 pound of sodium arsenite.

Observations on May 15 showed that all treatments killed most of the leaves that were emergent at the time of spraying. The rootstocks were not injured by any spray used, however, and new leaves were appearing. The plots were observed at intervals throughout the summer but there was no evidence of further injury to the plant.

Conclusions

The noxious pond weed, spatterdock, was effectively controlled by removing the leaves five times during the spring and summer. Death and decomposition of the rootstocks began toward the base and proceeded to the apex.

The addition of inorganic fertilizers hastened the death of spatterdock when the leaves were cut. Four cuttings were more effective when fertilizer was used than five cuttings without fertilizer. Unfortunately, the fertilized plots were not isolated, making it impossible to determine which material was most effective. Other experiments are planned in which the fertilized plots will be isolated, and in which the rates of application of fertilizer will be varied.

In the experiments reported in this paper, the petioles were severed with a scythe. Underwater saws or mowing machines may be substituted for the scythes in ponds without underwater stumps.

Pulling the rootstocks one time gave an effective control of spatterdock. The plants died even though they were allowed to remain in

the pond. Casually, pulling would appear to offer the best method of controlling spatterdock since only one pulling was required. Actually, pulling was more labor-consuming than cutting. In deep water pulling would be entirely impracticable. Although this procedure may not be practicable on a large area, it presents a simple method of destroying the weed on small areas.

Spatterdock produces seed. The writers have no information relative to longevity of spatterdock seed, but it is known that the seeds of some members of the waterlily family may remain dormant for many years and then germinate. It is evident that the plant may reestablish itself from seed unless the seedlings that appear in subsequent years are destroyed.

Chemical treatments were not successful in destroying spatterdock. Although the emergent leaves were killed by the sprays used, the rootstocks were uninjured. Repeated spraying should control the weed, but the cost would be prohibitive.

FURTHER OBSERVATIONS ON ULCER DISEASE OF TROUT

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ABSTRACT

Brook trout were fed various meat and meal mixtures to which vitamins A, B_1, C, D, G, and PP were added. None of these diets or vitamins affected the resistance of the trout to ulcer disease. Trout on a "natural" diet of insects, minnows, etc., succumbed to the disease. Infected fish planted in a small stream plentifully supplied with food organisms continued to die from ulcer disease. Ulcers have been found on wild fish, and on hatchery fish a year after planting in natural waters.

Feeding diseased tissue did not prove a more certain method of infecting trout than did contact with diseased individuals. Ingestion of diseased tissue, controlled to prevent external contamination, did not produce ulcer disease in brook trout yearlings. Trout were infected through contact of an open wound with kidney tissue from a diseased fish. An attempt to prevent ulcer disease by drastic treatment with potassium permanganate was unsuccessful. Data are presented on the effect of low temperatures in retarding the disease.

Strains of brook trout from hatcheries long infected proved much more resistant to the disease than did other strains.

Ulcer disease and fin rot have been shown to be identical diseases.

INTRODUCTION

The experiments and observations on ulcer disease described in this paper have been made since the summer of 1938. Some of them are repetitions, for purposes of verification, of previous experiments. Since considerable reference is made throughout this paper to the previously published experiments (Wolf, 1939), it has seemed best to continue numbering from the point where the previous experiments left off.

EXPERIMENTS AND OBSERVATIONS

19. Effect of various diets and vitamins on resistance to ulcer disease in fingerling brook trout.—During the winter of 1937-38 an experiment was performed to determine whether the resistance to ulcer disease of yearling brook trout (*Salvelinus fontinalis*) could be affected by their diet (Wolf, 1939; Exp. 18). The results were suggestive, but not conclusive, so it was decided to repeat the experiment. In this repetition the identical diets were used except for a modification in the vitamin supplements. The diets were as follows:

Diet I. Fresh meat 50 per cent, consisting of equal parts of pork spleen and fish. Dry meals 50 per cent, consisting of equal parts of cottonseed meal, skim milk, and fish meal.

Diet II. Same as diet I, but with the addition of vitamins as described below.

Diet III. Fresh meat 75 per cent, as in Diet I. Dry meals 25 per cent, as in Diet I.

Diet IV. Same as Diet III, but with the addition of vitamins as in Diet II.

Diet V. Fresh meat 75 per cent, consisting of equal parts of pork spleen, fish, and beef liver.

Diet VI. Same as Diet V, but with the addition of vitamins as in Diet II.

The diets were made up fresh twice a week. In the previous experiment the vitamin ingredients used in Diets II, IV, and VI were orange juice, cod liver oil, and yeast. Only limited amounts of these ingredients could be used because they tended to make the food too fluid for satisfactory feeding. In the present experiment more concentrated sources of vitamins were used, so that larger doses could be incorporated into the food without changing its physical consistency. In Table 1 are listed the vitamin substances used.

Table 1.—Vitamins added to Diets II, IV, and VI

Trade name of product	Amount per 100 grams of food	Vitamin	Vitamin units per 100 grams of food[1]	Vitamin units fed daily per 100 grams of trout[2]
Carex[3]	20 milligrams	A	100 International	2.2 International
Betaxin[4]	0.35 milligrams	B_1	105 International	2.3 International
Ryzamin-B[5]	35 milligrams	B_1	2.8 International	0.06 International
Vitamin C Roche	20 milligrams	C	400 International	8.8 International
Cod-liver oil	2 grams	A	3,500 U.S.P. X	77 U.S.P. X
		D	466 U.S.P. X	10.2 U.S.P. X
Fleischmann's irradiated dry yeast	10 grams	B_1	80 International	1.76 International
		D	3,600 U.S.P. X	79.2 U.S.P. X
		G	200 Sherman	4.4 Sherman
Nicotinic acid	10 milligrams	PP	10 milligrams	0.22 milligrams

[1]Units computed from manufacturer's statements.
[2]Each 100 grams of trout consumed 2.2 grams of food daily until disease induced loss of appetite.
[3]Carotene in oil.
[4]Crystalline vitamin B_1 hydrochloride.
[5]Rice polishings concentrate.

Because of the nature of the vitamin substances it was impossible to estimate accurately the number of vitamin units used in the previous feeding experiment. It is certain, however, that in the present experiment the dosage was larger.

The diets were first fed on August 18, 1939. From that date until September 19 the fish were continued on the experimental feeds, thus allowing 1 month for the food to affect their condition. During that period no fish died, and all appeared to have good appetites.

On September 19 ulcer disease was introduced. Two diseased yearling brook trout were chopped up and mixed with enough hatchery ration to provide an adequate feeding for all twelve groups. This procedure was repeated on each of the 5 following days, after which the experimental diets were resumed for the duration of the experiment.

As has been true in most of the experiments at the Rome, N. Y., laboratory, many of the first fish to die exhibited no external lesions. This period of indefinite symptoms soon gave way, as usual, and there-

after the regular and unmistakable lesions were present on every fish which died.

By November 28 the food consumption had diminished to a great extent in all groups, and it was obvious that the nature of the food supply could no longer have any effect upon resistance to the disease. The experiment was therefore terminated in spite of the fact that there were still fish surviving in each of the lots.

Final mortality figures are given in Table 2. The death rate was so nearly uniform in all the groups that nothing would be gained by presenting weekly mortality figures.

Table 2.—Total mortality in the 12 lots of brook trout fed various diets

Item	Diet number					
	I	II	III	IV	V	VI
Mortality in first groups	52	60	56	67	65	62
Mortality in second groups	68	73	59	64	63	73
Total mortality	120	133	115	131	128	135

Of the fish which survived at the termination of the experiment not one was free from positive symptoms of ulcer disease, and it is highly probable that every one would have died if the experiment had continued a few weeks longer. It is pointless to disregard the condition of the survivors and to draw conclusions from the mortality figures alone, but even if this is done it would be hard to make a convincing case for any one diet as compared to the others.

The experiment proves conclusively that the addition of the vitamins was in no way beneficial to the trout. In fact, the mortality in the vitamin-fed groups (II, IV, and VI) was in each case higher than that in the comparable groups which were given no vitamin supplement (I, II, and V). This result contradicts the conclusions tentatively considered in the previous diet experiment, namely: "They suggest that the addition of vitamins to a diet containing 50 per cent fresh meat may be beneficial, but that when the diet contains as much as 75 per cent fresh meat no benefit is to be derived from the addition of vitamins" (Wolf, 1939, p. 150). At present even the first part of the statement seems unwarranted.

The present work can, of course, lead to no final word on the subject of vitamins. The quantities used may have been so far from correct that the true effects of the substances were not revealed. Nothing is known about the amounts of the various vitamins required by trout. It seems, however, that vitamin therapy has little to offer in combating ulcer disease.

Summary: The addition of vitamins A, B_1, C, D, G, and PP to diets consisting of various combinations of fresh meat and dry meals had no beneficial effect on brook trout as indicated by resistance to ulcer disease.

20. Effect of natural diet on ulcer disease in brook trout yearlings.—

On May 16, 1940, six ulcered and six healthy brook trout yearlings were placed in a large aquarium. Throughout the 44 days of the experiment these fish were fed entirely on living food organisms. Six feedings consisted of earthworms, eight of blacknosed dace, one of crayfish, and seven of aquatic and terrestrial insects.

All of the healthy fish consumed the food freely from the start, but three of the ulcered specimens did not at any time show much interest, and this in spite of the fact that all had still been feeding freely up to the day they were placed in the aquarium.

On May 26 a brilliantly-colored wild brook trout, 5 inches in length, was added to the 12 fish already in the aquarium.

On June 29 the experiment was terminated. At this time only one of the originally ulcered fish remained, and this specimen was both ulcered and fungused. All the rest had succumbed to the disease. Four of the originally healthy hatchery trout remained, two with ulcers and one covered with tufts. The fourth survivor was apparently on the road to recovery. This fish bore several scars from small, healed ulcers, its fins were in good condition, and the only lesion of any sort was a small sore on the edge of the jaw. The wild fish had died showing positive symptoms of disease in the form of epithelial tufts.

Summary: A diet consisting entirely of living organisms had no effect in checking disease in ulcered fish, nor did it prevent healthy fish from contracting the disease.

21. Fate of diseased brook trout planted in natural waters.—Up to the present writing no fingerling, and only one yearling, brook trout of the stock raised at the Rome hatchery has ever recovered entirely from ulcer disease in any of the experiments. The following study was designed to give some information on the question of what happens to diseased fish when planted in natural waters.

The stream selected for the experiment was a small spring run located near the Rome hatchery. No fish existed in this run. Its temperature was perfectly suited to brook trout. Shelter conditions were very poor, to remedy which planks were placed in the water. A single alder clump provided a few feet of natural cover. The stream was well supplied with fresh-water shrimp of an undetermined species. Screens were placed across the run 120 feet apart, so that the fish could not escape from the enclosed area, and the experiment was conducted within the confined area.

On May 16, 1940, 12 yearling brook trout which showed mild early symptoms of disease (no ulcers), and 3 ulcered fish were placed in the stream. Observations were made on these fish almost daily. Some quickly assumed a brilliant coloration, a certain indication that they were feeding on the shrimp in the stream, but in spite of such hopeful signs every fish died, or disappeared, in the end. It is almost certain that the fish which disappeared were taken by birds which began to frequent the run toward the end of the experiment.

Eleven dead fish were recovered, of which 6 had positive ulcer-disease symptoms and 5 were too decayed to allow recognition of such symptoms. Since not one of the recovered trout was clearly free from symptoms of the disease, it is highly probable that all 11 died from the malady. At the conclusion of these observations 15 healthy brook trout were placed in the stream to determine whether they would contract the disease. All quickly fell victims to birds, so that no information was obtained.

Summary: Only long-continued observations can furnish any safe basis for predicting the fate of brook trout afflicted with ulcer disease when planted in natural waters. The results obtained in this particular instance indicate that of the stock of trout here used none recover. For more data on this subject see Experiments No.'s 22, 30, and 31.

22. Ulcer disease in native fish.—During the past 3 years the writer has examined numerous ulcered brook trout taken in ponds and streams of New York State. In every instance it has been possible to trace a shipment of diseased or suspected hatchery fish to the locality where the ulcered fish were caught. Most of the fish examined were caught at last a full year after the shipment was made, and some were apparently wild fish which had contracted the disease from stocked hatchery trout. This indicates that the disease is able to maintain itself for some time under natural conditions, although the ultimate history of the disease under such conditions is not yet known.

An interesting observation was made on all these specimens, not one had badly frayed fins. All had ulcers—which was the reason they were sent in for examination—but most had perfect fins. A few had slight fin lesions, but too slight to furnish a basis for diagnosis of the disease. A few had epithelial tufts.

Summary: Ulcer disease is able to maintain itself under natural conditions in natural waters for at least a few years, perhaps indefinitely. In native fish, or in hatchery fish long in natural waters, the disease produces ulcers on the bodies of the fish, but fins are almost immune to attack.

23. Relative susceptibility of yearling brown and rainbow trout to disease by contact and by feeding.—In experiments performed previously a 71-day exposure to ulcer disease by contact with diseased brook trout failed to produce the disease in yearling brown and rainbow trout. On the other hand, three feedings with tissue from ulcered brook trout successfully produced an infection in a few yearling brown trout, though not in rainbow trout (Wolf, 1939, Exp. 4 and 5). It seemed advisable to repeat these experiments, for if infection can be more easily transmitted by feeding than by contact this fact sheds important light on the nature of the disease.

On June 6, 20 healthy yearling rainbow trout were placed in each of 2 troughs, and 20 healthy yearling brown trout in each of two additional troughs. Each trough had its individual water supply.

Five ulcered yearling brook trout were placed with one of the rain-

bow trout and one of the brown trout lots, and left there until the termination of the experiment. The other two lots were fed for 6 consecutive days on a mixture containing ulcered tissue, and thereafter on uncontaminated food.

On July 22 final observations were made, and the experiment terminated. No brown or rainbow trout had died in any of the lots. The rainbow trout fed on diseased tissue showed no signs of infection. The brown trout fed also on ulcered tissue showed a few small tufts. The rainbow trout in the trough where the diseased fish had been placed were the worst of all the groups. Nineteen of these fish had epithelial tufts, though none had ulcers. In the disease-contact brown trout eight showed early symptoms of infection.

Summary: Six feedings of tissue from ulcered brook trout did not produce any symptoms of ulcer disease in yearling rainbow, and only mild symptoms in yearling brown trout. A 46-day exposure to the disease by contact with ulcered brook trout produced positive symptoms, but caused no deaths, in yearlings of both species. This experiment therefore did not confirm the conclusion previously suggested regarding the two methods of transmission. The experiment also proved that rainbow trout are not entirely immune to the disease.

24. Relative susceptibility of yearling brook trout to disease by feeding on ulcered tissue and by contact with contamination from such tissue.—A rearing trough was divided by fine-meshed copper screens into four compartments. Nine healthy yearling brook trout were placed in the upper compartment, and nine in the lower. The two middle compartments were kept empty.

For 3 consecutive days the fish in the upper compartment were fed chopped tissue from ulcered brook trout. Thereafter only uncontaminated food was used. The fish in the lower compartment received only uncontaminated food at all times. By this arrangement disease organisms introduced with the food into the upper compartment would be carried by the flow of water down to the lower compartment. Food particles could not be carried down, however, due to the three screens interposed between the two groups of fish.

Four hours after the third and final feeding of contaminated tissue the fish in the lower compartment were removed to a separate, uncontaminated trough. This was done so that these fish would not be subjected to secondary infection from fish in the upper compartment which might have contracted the disease. The fish were kept under observation for 22 days, at the end of which time both lots had contracted the disease, and in about equal measure.

Summary: This experiment indicates that in cases where the disease has apparently been transmitted by feeding diseased tissue, the simultaneous external contamination which takes place is sufficient to account for the infection.

25. Transmission of ulcer disease by ingestion of diseased tissue.—The following experiments were performed to determine whether the

ingestion of diseased tissue, in the complete absence of any external contact with disease organisms would transmit the infection.

(*a*) *Ingestion of ulcers:* Diseased tissue was introduced directly into the stomachs of four healthy brook trout yearlings. Ulcers were cut from the sides of diseased fish and inserted in gelatin capsules, care being taken not to contaminate the surface of the capsules. A capsule was forced into the stomach of each of the four healthy fish, which were then placed in individual aquaria for observation. The trout were observed for 34 days, but during that time no symptoms of ulcer disease appeared.

(*b*) *Ingestion of entire ulcered fish:* A small, ulcered, fingerling trout was killed and then forced into the stomach of a yearling. No antiseptic measures were used, but great care was exercised in the manipulation of the fish to prevent the diseased fingerling from coming in contact with the exterior of the yearling. The yearling trout was then placed in an aquarium, and kept under observation for 59 days. No symptoms of ulcer disease developed.

Summary: In neither of these experiments was ulcer disease transmitted by ingestion of diseased tissue. It appears that the disease is transmitted only by external contact.

26. Presence of disease germs in internal organs of infected fish.—Macroscopical examination of the internal organs of disease fish has never revealed pathological symptoms (Fish, 1934; Wolf, 1939). Fish stated, however, that "Microscopic areas of necrosis . . . . have been found in the liver and some tubular necrosis in the kidneys if heavily infected hosts sacrificed at the point of death." He added that these areas showed no evidence of bacterial invasion. Such areas have not been observed by the writer.

As was pointed out previously (Wolf, 1939), there is some reason for thinking that the causative organism can pervade the body of the fish. The following experiments were performed to test this theory.

(*a*) *Heart-blood and kidney:* An ulcered fish was killed and cut open in such a manner as not to contaminate the internal organs. The heart of this fish was then removed with sterilized instruments, and rubbed into a cut made in the side of a healthy brook trout yearling. With fresh instruments a part of the kidney was removed from the ulcered specimen, and rubbed into a cut made in the side of a second healthy brook trout yearling. The two fish were kept under observation in separate aquaria for 32 days. At the end of this time the cut in the heart-infected fish had healed without at any time showing the slightest sign of inflammation or disease. The cut of the kidney-infected fish, however, became inflamed, and developed into a typical ulcer.

Summary: Infection was not transmitted through the heart-blood of a diseased fish, but was transmitted through the kidney of such a specimen.

(*b*) *Kidney of healthy and diseased fish:* Two healthy brook trout yearlings were killed, and parts of their kidneys removed with due

precautions against contamination. This kidney tissue was rubbed into cuts made in the sides of two healthy yearlings. Four ulcered trout were killed and dissected in the same manner, and their kidney tissue rubbed into cuts in four other healthy yearlings. A single kidney was used to infect a single fish. The six fish were then placed in individual aquaria for observation which was continued for 33 days. At the end of this time the cuts in the first two, and in two of the last four fish had entirely healed without at any time having shown signs of infection. In one of the remaining two trout the cut had partly healed, but the open region was inflamed and diseased. In the last fish the cut had not healed at all, but had become the site of a deep, red ulcer.

Summary: No infection was transmitted from the kidneys of two healthy brook trout, but was transmitted from the kidneys of two out of four diseased specimens. This indicates that disease organisms are present in kidneys of diseased fish, at least in some individuals.

(*c*) *Spleen and liver:* In a manner similar to that described above an attempt was made to infect two yearling brook trout from the spleens and livers of two ulcered specimens. This attempt was unsuccessful, indicating that in these diseased fish the spleens and livers did not harbor infectious organisms.

Summary: The series of experiments described above indicates that in some cases the causative organisms of ulcer disease can be found in the kidney of diseased fish. They have, so far, not been found in other organs.

27.—Attempted sterilization of infected fish with potassium permanganate.—Two healthy brook trout yearlings were held for 3 days in a trough containing ulcered fish. At the end of this time one of the fish was removed directly to a sterilized aquarium. The second was thoroughly swabbed with cotton saturated with a 1 per cent solution of potassium permanganate, and immediately thereafter held for 30 minutes in a container filled with 1:50,000 solution of the same chemical. This fish was then placed in a sterilized aquarium like the first, and the two were watched for signs of disease. Seventeen days after the beginning of the experiment the untreated fish died. At death the specimen exhibited several epithelial tufts, proving that it had contracted ulcer disease. Five days later the treated fish also died, likewise exhibiting epithelial tufts.

Summary: In spite of the drastic treatment with potassium permanganate, administered long before any symptoms of disease were present, a yearling brook trout developed an infection. This result agrees with the findings previously recorded (Wolf, 1939; Exp. 14). In the light of those findings it does not appear that the use of potassium permanganate as a preventative for ulcer disease is likely to prove effective. Furthermore, if the results of Experiment 26 are confirmed, any surface treatment of infected fish appears to be illogical.

28. Effect of temperature on progress of the disease.—On January

31 two groups of twelve 1-year old brook trout were placed in separate troughs. Several ulcered yearlings were placed in each group, and were kept there throughout the experiment. Although the experiment was run in duplicate the progress of the disease was quite uniform in the two groups. The water supply for these fish came from the bottom of a lake whose temperature hovers around 34° F. during the winter.

Previous experiments have shown that at a temperature of 52° F. the first epithelial tufts appeared in from 2 to 3 weeks after infection, the first ulcers in from 3 to 5 weeks after infection, and the first deaths within the same period (Wolf, 1939). In the present experiment it was found that at a temperature of 34° F. the first epithelial tufts appeared at the end of 3 weeks, or within about the same length of time required at the higher temperature. Thereafter, however, the disease progressed much more slowly at the lower temperature. No symptoms other than epithelial tufts appeared until the twelfth week after the beginning of infection, and it must be noted that by this time the water had begun to warm (38° F.). Not until the sixteenth week did a fish die, at which time the temperature had reached 52° F. At the end of the sixteenth week the first body ulcer was observed, and the temperature had reached 54° F.

Summary: Ulcer disease proved transmissable at 34° F., at which temperature it required about 4 weeks to produce epithelial tufts on previously healthy fish. The disease did not progress much beyond this point until the temperature went up to around 38° F., when sores appeared on the jaws of the fish. Real body ulcers and mortality did not occur until the temperature reached the neighborhood of 50° F.

29. Resistance to ulcer disease of various strains of brook trout, I.— In the experiments performed by the writer it has been found that young brook trout fingerlings appear to be immune to ulcer disease until some time in June, thereafter becoming highly susceptible. As yearlings this species develops some resistance, and 2-year old fish often recover from infection.

There is some evidence that brook trout have acquired a higher degree of resistance in hatcheries where the disease has long been present (Wolf, 1939; Exp. 16). In order to examine this possibility fingerling brook trout from two New York hatcheries where the disease has long been endemic were tested against fingerlings from a commercial hatchery known to be free from the disease. The commercial stock was that used in all other experiments described both in this paper and in previous publications of the writer. It will be called "Rome" stock in this experiment. The two state stocks came from the Randolph and the Caledonia hatcheries.

The experiment was performed in duplicate, so that six groups of fish were involved. Each group consisted of 50 fingerlings. On July 22, 1938, infection of these groups by the contact method was started, and was continued until August 20, by which time all groups were

well infected. The weekly mortality record for the six lots is given in Table 3. The data show conclusively that the Rome fish were more susceptible to the disease than were the Randolph and Caledonia strains. It is interesting to observe that the two latter strains had acquired about the same degree of resistance.

Table 3.—Mortality from ulcer disease of three strains of brook trout fingerlings

[Mortality given in 7 day periods]

Date	Rome strain		Randolph strain		Caledonia strain	
	Group 1	Group 2	Group 1	Group 2	Group 1	Group 2
Aug. 14	....	....	[1]1	....	....	[1]4
Aug. 21	....	....	0	....	[1]2	[1]4
Aug. 28	3	....	0	....	[1]3	[1]4
Sept. 4	4	4	0	2	0	0
Sept. 11	7	8	2	1	0	0
Sept. 18	16	12	2	2	2	0
Sept. 25	8	10	2	0	2	2
Oct. 2	4	5	4	2	3	3
Oct. 9	4	6	6	2	2	0
Oct. 16	1	2	4	0	1	2
Oct. 23	2	2	6	4	4	4
Oct. 30	1	1	2	6	3	2
Nov. 6	....	....	2	3	2	3
Nov. 13	....	....	1	3	3	2
Nov. 20	....	....	2	1	4	1
Nov. 27	....	....	2	2	3	2
Dec. 4	....	....	1	1	1	0
Dec. 11	....	....	1	1	0	0
Dec. 18	....	....	0	0	1	0
Total	50	50	38	30	36	33

[1]No symptoms of ulcer disease.

The fact that strains differ in resistance makes it necessary to exercise caution in predicting the exact course of the disease in different hatcheries. Since all the writer's experiments have been conducted with a highly susceptible strain, it follows that his findings probably present a worse picture than will be encountered in hatcheries where the disease has long been established.

The 63 surviving Randolph and Caledonia trout were kept under observation for 6 months after the termination of the experiment. During those 6 months nine more Randolph and five more Caledonia fish died.

Summary: Two strains of brook trout from hatcheries infested with ulcer disease showed much more resistance to infection than did a strain from an uninfected hatchery. The two resistant strains showed the same degree of resistance.

30.—Resistance to ulcer disease of various strains of brook trout, II. —The previous experiment was repeated during the autumn of 1939, using a greater number of strains. Brook trout fingerlings were obtained from six different sources. The first two lots were from two of the strains used in the previous work, namely, Randolph and "Rome." The other four strains were from commercial hatcheries where information concerning the absence or presence of ulcer disease was not known.

The procedure in this experiment followed closely that described above, so that the details need not be given again. Suffice it to say that the experiment was conducted with duplicate groups of 50 fish each for all six strains. The work was begun later in the fall than the preceding experiment, and therefore had to be continued until later in the following spring. Observations were terminated on April 8, at which time only the Randolph strain still survived, 28 fish being left in one of the Randolph groups and 27 in the other. The five strains which succumbed showed some small differences in resistance, but none approached the Randolph in this respect. The experiment was therefore unsuccessful in discovering any strain superior to the Randolph.

Summary: A strain of brook trout from a hatchery long infected with ulcer disease proved superior in resistance to five strains from commercial hatcheries. The results furnish presumptive evidence that the commercial hatcheries were uninfected.

31. Identity of Ulcer Disease and Fin Rot.—Fish (1934) has pointed out the similarity between ulcer disease and fin rot. Davis, who originally described fin rot (1929), has done the same, and has stated (1937) that: "The writer is strongly inclined to believe that both diseases are caused by the same organism."

Not until the fall of 1938 did the writer have an opportunity to observe an outbreak of fin rot. This occurred at the Van Hornesville, New York, state fish hatchery. The disease conformed in every respect to that described by Davis. The fish involved were fingerling brook trout of the identical strain used in all the writer's experiments at Rome. The condition was first noticed in September, but not until October was there a slight increase in mortality in a few of the ponds.

On October 28 some of the diseased Van Hornesville fish were brought to the Rome laboratory and used to infect healthy fingerlings. In the Van Hornesville fish the disease at this time was still confined almost entirely to the dorsal and pectoral fins, the former being much more affected than the latter. In a very few specimens disintegration of the dorsal fins had proceeded to the point where the skin at the base of the dorsal fin appeared somewhat blistered.

On November 29 an individual examination of the Rome trout which had been infected from the Van Hornesville fish showed the presence of typical ulcer disease. By this time the surviving Van Hornesville fish also showed characteristic ulcer-disease symptoms. Infection of Rome fish from Van Hornesville fish was repeated several times, and in every case the Rome fish developed unmistakable ulcer disease. At Van Hornesville the disease grew steadily worse, and body lesions became common on the fish. To the end of January, however, fin-rot symptoms predominated.

Smears made from the fins of fish at Van Hornesville in October, and from ulcers in January, were stained, and numerous small, rod-shaped, Gram-negative bacteria were present in all. Bacteria of identical appearance have always been found in the lesions of ulcer disease

at Rome. Davis (1929, 1937) asserted that a rod-shaped bacterium is the causative organism of fin rot. Fish (1934) found a short, Gram-negative, rod-shaped bacterium present in all types of ulcer-disease lesions. Until more is known about this bacterium it cannot positively be considered the cause of either disease, and the subject is mentioned here only to point out that the writer's findings, so far as they go, are in agreement with those of Davis and Fish.

It is difficult to understand why the disease produced somewhat different symptoms during its initial period at Van Hornesville and Rome. At present the difference would seem to be attributable to some environmental factor rather than to a difference in virulence of the two strains of disease organisms. The final course of the fin rot at Van Hornesville has been recounted in another place (Wolf, 1940).

The writer is of the opinion that the term "fin rot" should be abandoned as a name for a specific disease. Correctly used it should apply only to one particular fin condition which is a manifestation of ulcer disease, and to which, in the writer's experiments, only brook trout have proved easily susceptible. Although the final word on species susceptibility has not been spoken, it is, nevertheless, highly probable that the numerous pathological fin conditions found in brown trout and rainbow trout fingerlings are not "fin rot" or ulcer disease.

Confusion of these relatively harmless fin conditions with fin rot has, no doubt, furnished support for the belief in the efficacy of copper sulphate treatments. Hatchery foremen have called many disorders "fin rot," have treated the fish with copper sulphate, and then optimistically attributed a cure to the treatment. The fish would probably have recovered equally well without benefit of $CuSO_4$.

Summary: Observations on the progress of fin rot, and experiments in infecting healthy fish, have shown this malady to be identical with ulcer disease. Bacteriological investigations, so far as they went, added confirmatory evidence.

Conclusions

1. Addition of vitamins A, B_1, C, D, G, and PP to three different hatchery diets failed to affect the resistance of brook trout to ulcer disease. A diet composed entirely of living organisms such as wild trout consume did not check the disease. Infected trout, placed in a natural environment rich in food organisms, died from the infection. Ulcer disease has been observed in hatchery trout more than one year after they were planted in wild waters, and in wild fish which had been subjected to infection from planted hatchery stock. From these facts it is concluded that there is litle hope of checking the disease through improvements in the diet of fish in our hatcheries.

2. Ulcer disease is transmitted through external contact with the causative organism. Attempts to transmit infection through ingestion of diseased tissue have not succeeded.

3. Infection has been transmitted through contact with kidney tissue of diseased trout, but not through contact with other internal organs. This supports the conclusion, previously drawn from the frequent deaths of diseased fish without external lesions, that ulcer disease is not merely a surface infection.

4. Copper sulphate and potassium permanganate baths have proved ineffective in checking the disease.

5. Low water temperatures retard the progress of the disease, but do not prevent spread of infection.

6. Rainbow trout have been shown to be not entirely immune, but highly resistant to infection. Strains of brook trout from hatcheries long infected proved much more resistant than strains from uninfected hatcheries. A few individuals in the resistant strains appeared to be immune.

7. Proof is advanced that fin rot and ulcer disease are one and the same infection. Differences were observed in the initial stages of the disease in different hatcheries, but when transferred to the same hatchery the diseases became identical.

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AN EXPERIMENT IN REMOVING COARSE FISH FROM A LAKE[1]

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ABSTRACT

The gradual increase in turbidity, the disappearance of vegetation, and the decline in availability of game fish over a period of years in Bass Lake, Indiana, was attributed to an overabundance of carp. Under the supervision of the Division of Fish and Game, coarse fish were removed by seining in 1935 and 1936. The total weight of carp removed was 45 tons, of quillback suckers 20 tons and of buffalo fish 6 tons. Other species of coarse fish were taken only in insignificant quantities. The removal of these fish appeared to reduce very considerably the population of carp and quillback suckers, and possibly buffalo fish as well, as shown by smaller average catches per haul in 1936 than in 1935.

In 1936 the water of the lake cleared and vegetation increased in extent and density. The abundance of game fish increased rapidly in the second half of 1936, as shown by a manifold increase in the number caught of wall-eyed pike, striped bass, smallmouth and largemouth black bass, bluegills, black crappie and yellow perch. At the same time angling success improved greatly. Up to 1940 there has been no significant reversion to conditions existing prior to 1935.

DESCRIPTION OF THE LAKE

Bass Lake is in Starke County, Indiana, near the eastern border of the sandy northwestern section of the State. It is shallow, the maximum depth being 30 feet, and the average depth about 10 feet. Its area is 1,600 acres at high water; but seasonal fluctuations may reduce this considerably, exposing large areas of bottom at the southern end. Because its water is nowhere permanently stratified in summer, high temperatures prevail from surface to bottom at that season. The bottom is for the most part composed of sand or stones near shore, but mud appears farther out. Aquatic vegetation at present (1940) consists of a rather sparse growth of bullrushes (*Scirpus*) offshore, and a fair quantity of submerged vegetation beyond it. In more protected situations spatterdock and white water lilies occur, along with denser stands of bulrush, and a thicker marginal zone of *Potamogeton, Myriophyllum* and other submerged plants. In general, however, the vegetation of the lake is much less profuse than in other large Indiana lakes such as Wawasee, Maxinkuckee or Winona.

HISTORY OF FISHING IN THE LAKE

Like all large lakes in a densely populated region, Bass Lake is fished intensively by anglers. The principal game fish caught are wall-eyed

[1]Contribution No. 288, Department of Zoology, Indiana University.

pike and striped bass, the latter species said to have been first introduced to the lake by the Indiana Fish and Game Commission about 1915. Less numerous but more highly esteemed are the smallmouth and largemouth black bass, of which the former appears to be the more numerous, contrary to the situation in most Indiana lakes. In addition, various kinds of panfish occur in considerable numbers.

In the early 1930's it was apparent that Bass Lake had deteriorated as a habitat for game fish. Complaints that fishing was poorer than in former years, to which an administrator usually listens with profound sympathy and skepticism, were in this instance backed up by two apparent physical changes: the water of the lake had become permanently muddy, and vegetation had become very scarce. It is difficult to say just when these changes began to become noticeable, as they apparently developed over a considerable period of years. By 1934 the situation had become so serious, and complaints so numerous, that remedial measures were decided upon. Of the various diagnoses offered to explain the increased turbidity, the suggestion that the water was being muddied and vegetation uprooted by an excessive population of carp or other coarse fish appeared to be the most plausible. Most suspicion was directed against the carp, because it was supposed to be a relatively recent addition to the lake's fauna, probably having come in from the Yellow River during a period of exceptionally high water in 1915 or 1916.

Method of Removing Coarse Fish

Proceeding on the above hypothesis the Division of Fish and Game authorized the removal of coarse fish from the lake in 1935 and 1936. Two seines were procured: a large one 1,000 feet long and 20 feet deep, and a smaller one 800 feet long and 8 feet deep. Both were of netting 1½ inches square mesh (3 inches stretched measure). Winches were used to haul these seines to shore, after they had been set from a scow. The presence of hard sand beaches made the use of these large seines practical, although some trouble was encountered with mud before the most favorable seining grounds were located. Labor was supplied principally by the W. P. A., but was at times contributed by volunteers from conservation clubs, and by local residents. The project was directed by the Division of Fish and Game, and was under the immediate supervision of the late John Metz, of the Bass Lake fish hatchery.

The careful records kept by Mr. Metz and forwarded every week to the Indianapolis office form the basis of the numerical data to be presented. Each day's catch was segregated into its component species, and the number of fish and the total weight of each species recorded. Weights are given to the nearest pound, and hence are reliable except where only a few individuals of the smaller species occur. In addition, the number of hauls made each day is usually, though not always,

recorded. Unfortunately, there is no extant record of the place where each haul was made. Most of them, however, were taken either at the northeast corner of the lake near the hatchery, or along the State-owned beach on the east side near the south end.

Coarse Fish Removed

Detailed records of the catch of all coarse and game fish by weight and by number are available and have been summarized by semi-monthly periods. Because of their bulk the data are not presented in detail but form the basis of the following summaries and of the analyses presented in other portions of this paper.

The following total numbers of coarse fish were removed from Bass Lake during the years 1935 and 1936:

Carp (*Cyprinus carpio*): A greater weight of carp was removed than of any other species—45 tons in all; 12,281 individuals were killed, averaging 7.35 pounds each in weight.

Quillback (*Carpiodes* sp.): Quillback or "highfin" suckers were taken more numerously than any other kind; 14,456 were killed, averaging 2.70 pounds in weight.

Buffalo fish (*Megastomatobus* and/or *Ictiobus* spp.): These were much scarcer than the two preceding; 1,441 were killed, of 8.55 pounds average weight.

Suckers: In some hauls these were tabulated as "white suckers" (presumably *Catostomus commersonnii*) and "black suckers" (possibly *Minytrema melanops*). Neither was common; only 65 were taken, of 2.03 pounds average weight.

Gar pike: Both long-nosed and short-nosed gar pike (*Lepisosteus osseus* and *L. platostomus*) were taken, the former being about three times as numerous as the latter. A total of 215 was captured and their average individual weight was 2.21 pounds.

All of the above so-called coarse fish were killed immediately after capture.

Game Fish Captured

The following total numbers of game species were taken together with the coarse fish and were returned to the water immediately:

Wall-eyed pike (*Stizostedion vitreum*), 1,605, average weight 2.81 pounds.

Striped bass (*Lepibema chrysops*), 1,658, average weight 1.01 pounds.

Smallmouth black bass (*Micropterus dolomieu*), 431, average weight 2.0 pounds.

Largemouth black bass (*Huro salmoides*), 140, average weight 2.21 pounds.

Crappies (chiefly or entirely *Pomoxis sparoides*), 558, average weight 0.2 pounds.

Bluegills (*Lepomis macrochirus*), 1,081, average weight 0.13 pounds.

Sunfish (presumably the common sunfish, *Lepomis gibbosus*), 83, average weight 0.06 pounds.

Yellow perch (*Perca flavescens*), 1,249, average weight 0.08 pounds.

Rock bass (*Ambloplites rupestris*); taken only twice.

Catfish (*Ameiurus* sp.); taken only twice.

Efficiency of Two Nets

Attempts to assess the changes in abundance of fish between 1935 and 1936, are made difficult by the fact that two different seines were employed. In 1935 only the large net (1,000 by 20 feet) was used. In 1936 the small net (800 by 8 feet) was fished until the end of May, and from August to November, except for one haul of the big net September 2. In June there were 14 big hauls and 11 small, in July 12 big and 15 small, or 26 of each kind in the 2 months. From the catches of these two months some information concerning the relative efficiencies of the two nets can be had, as shown in Table 1. For most of the species listed, there was little difference in catch per haul of the two sizes of net; in catch of all species the small net exceeded the large one, but by a non-significant number. In a few species, however, rather striking differences were apparent. The quillback were seven times as abundant in the large net as in the small, but even this disparity does not indicate certainly a difference in catching power of the two nets, so great is the variation between hauls; and the isolated character of this occurrence makes it unlikely that any great difference in efficiency between the nets did exist. The much larger average catch of wall-eyed pike by the small net lies on the borderline of statistical significance; it may be partly ascribed, with probability, to an actual increase in number of wall-eyed pike during the second half of July, when nearly all hauls were made with the small net.

From the standpoint of seining efficiency, it is apparent that any differences between the two nets in no way compensated for the greater cost and greater difficulty of manipulating the large net. In fact it appears probable that since the small net could be hauled more often, more fish were taken per day when it was used.

Another complication is introduced by the fact that an accessory net was at times used with the seine. This was a trammel net 75 feet long and of 1 inch square mesh on the inner web, which was hung behind the middle of the seine when hauls were made. It was first used in early July, 1935, and was observed then to catch a considerable number of smaller fish which escaped the seine. Unfortunately, there is no record of how consistently it was used in the succeeding months.

Table 1.—Mean number of fish caught per haul, the standard deviation (S.D.) in number of fish caught,[1] and the average weight in pounds of individual fish in 26 hauls each of the big seine and of the small seine, taken in June and July, 1936

Species	Big Seine			Small Seine		
	Mean number	S. D.[1]	Average weight	Mean number	S. D.[1]	Average weight
Carp	28.1	31.1	8.52	38.8	41.7	6.51
Quillback	18.4	26.6	2.19	2.5	2.4	2.09
Buffalo	4.6	10.1	6.13	3.9	4.6	7.58
Gar pike	1.2	.....	2.17	3.5	.....	2.08
Smallmouth black bass	0.8	.....	1.73	2.0	.....	2.00
Striped bass	8.5	.....	0.77	9.2	.....	0.66
Crappie	2.0	.....	0.29	1.0	.....	0.24
Wall-eyed pike	1.2	1.9	2.50	7.0	9.3	2.62
Bluegill	1.0	.....	0.19	1.6	.....	0.20
Total	66.1	.....	.....	70.2	.....	.....

[1]When more than one haul was made in a day, the catches were lumped together. The average catch per haul for each day was therefore used in calculating the above standard deviations—a procedure which gives a result smaller than the real standard deviation of individual hauls. The number of days used was 18 for the big seine, 13 for the small seine.

Decrease in Abundance of Coarse Fish

In spite of irregularities in the kind of nets in use, it appears possible to make some use of the catch per haul as a measure of the abundance of fish at successive intervals of time. These data are presented in Figure 1, the catch per haul being computed semi-monthly. There was a general tendency for catches of carp to be smaller in 1936; the average in that year was 24.3, compared to 36.4 in 1935. The quillback exhibited a greater apparent reduction in availability—from 49.1 per haul in 1935 to 20.4 in 1936; and but for some extraordinary catches in November, the 1936 average would be much lower yet. The buffalo, however, showed very little difference in availability between the two years—3.8 per haul in 1935 and 3.5 in 1936. The only other important coarse fish are the gar pike, which showed a striking increase in availability between the 2 years, from 0.1 to 1.2 per haul, and in this respect resemble the game fish rather than the other coarse species.

Since independent evidence suggests that an important fraction of the coarse fish must have been removed in 1935, it is perhaps a matter of surprise that there is not a greater decrease in catch per unit of gear between the 2 years, particularly of carp. If this presents a difficulty, it may be remembered that number of seine hauls is even at best not an absolutely accurate measure of fishing effort. In this case, it is reasonable to suppose that the second year's work may have been considerably more efficient than that of the first, as the best seining grounds were then known, and also the best methods of handling the net. If this were true, the actual catch *per unit of effort* would be smaller in 1936 than the figures listed above indicate.

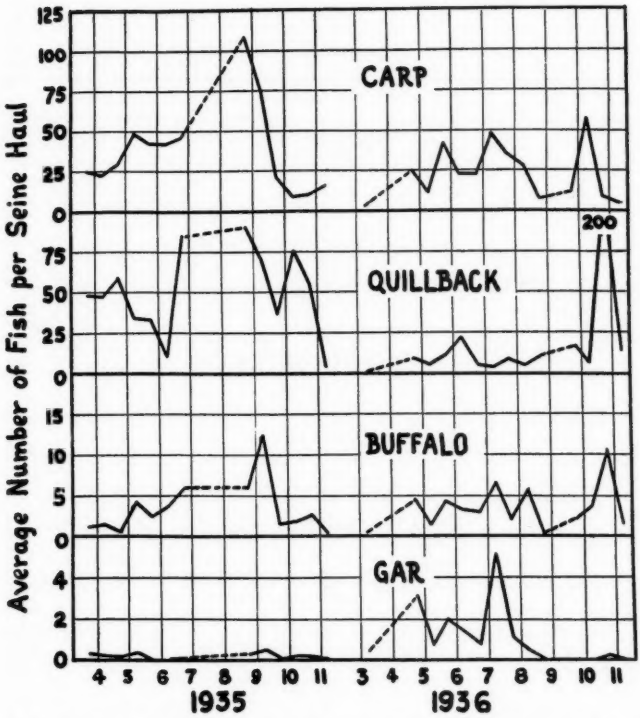

Figure 1.—Catch of coarse fish per seine haul by semi-monthly periods. The vertical lines are placed at the middle of each month.

Increase in Abundance of Game Fish

The tremendous increase in the number of game fish taken in 1936, particularly from August onward, is readily apparent in Table 1, and is plotted in Figure 2. The increase involved all game species taken in the lake, as well as the gar pike, which resembles the larger game fish in its feeding habits. Comparing the 2 years in their entirety, the average catch of wall-eyed pike increased from 2.3 to 5.8 per haul; of striped bass from 0.7 to 8.8; of smallmouth black bass from 0.5 to 1.9; of largemouth black bass from 0.1 to 0.6; of crappies from 0.2 to 1.9; of bluegills from less than 0.1 to 6.3; and in addition common sunfish and yellow perch appear for the first time

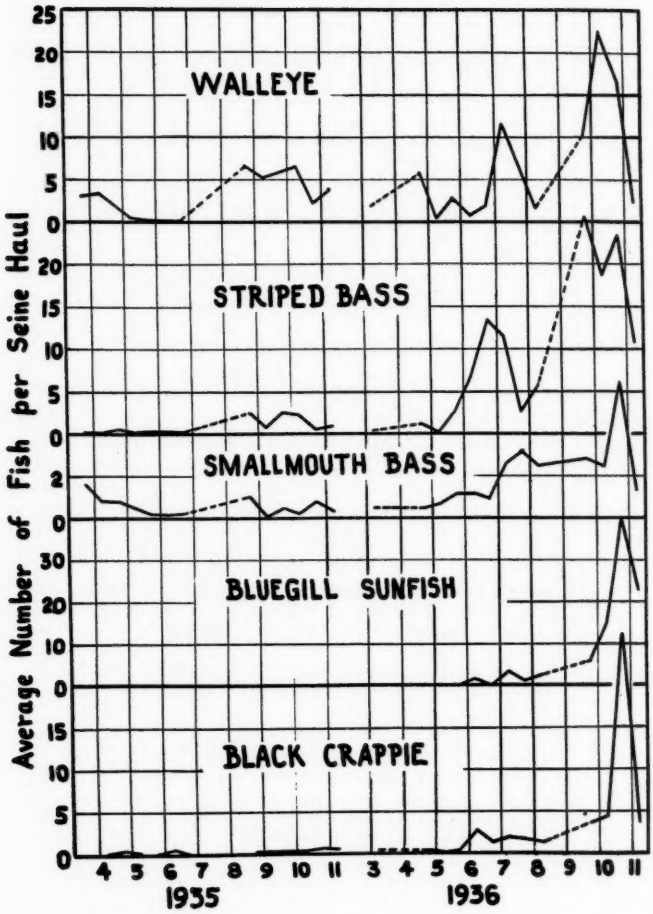

Figure 2.—Catch of game fish per seine haul by semi-monthly periods. The vertical lines are placed at the middle of each month.

in 1936, to the number of 0.5 and 7.4 per haul, respectively. If the suggestion of the preceding paragraph be followed, that seining was more efficient in 1936 than in 1935, then it will be necessary to discount these apparent gains in abundance to a greater or less extent. But even if the catches per haul in 1936 were to be divided in half, they would still indicate very substantial increases in numbers of game fish. To the evidence of the net catches may be added the testimony of anglers, who reported very much larger catches from 1937 down to the present.

Other Changes in the Lake

It remains only to record that in 1936 the other signs of biological unbalance in the lake—muddy water and absence of vegetation—were rectified. The lake today is of the blue color to be expected in a body of water which, though shallow, has no sediment-bearing tributaries. Where suitable bottom and protection are afforded, it supports vegetation in abundance; though as mentioned earlier it cannot rival the majority of Indiana's lakes in this respect.

As testimony of the rapidity with which these changes occurred, we may quote the late John Metz, who wrote on November 20, 1936 (*in litt.*): "I honestly believe that the vegetation has increased over 1,000 per cent and the water is clearer by 3 to 1 feet." Similar statements can be had from anyone familiar with conditions before and after the seining operations.

Discussion

In the above account of the changes in Bass Lake and its fish population we have tried to avoid the statement, though not the inference, that the improvements noted were the result of the removal of coarse fish. When the question of causation is critically examined, it appears impossible to doubt that the seining was in fact responsible for the benefits attributed to it. The only alternative explanation of the biotic changes would be a natural cycle of abundance which was being followed, independent of the human interference. It seems incredible, however, that any natural cycle could produce such an explosive increase in abundance of so many species of game fish as occurred in 1936; or that carp or other coarse fish could die in sufficient numbers in one year to make the difference between a barren and a vegetation-filled lake.

The question remains of how permanent will be the effects of this seining. There appears to be no basis for predicting that the lake either will, or will not, return to its former condition. It would certainly be rash to assert that a new crowd of coarse fish could *not* fill the lake, for it has happened once. On the other hand, in the majority of lakes these species, including carp, exist at a population level which permits large and stable populations of game fish; hence it would be equally rash to assert that balance will be impossible in Bass

Lake. Something depends upon the nature of the last epidemic, which cannot now be discovered: whether it was a gradual increase of many broods from year to year, or an overproduction of a single year-class of fish of one species resulting from unusually favorable spawning or growth conditions.

We must emphasize that, effective though it was in Bass Lake, seining of coarse fish is not a panacea for all of the real and imagined ills which may afflict a body of water. Following the Bass Lake experiment, an attempt was made to seine out various other lakes of the state. The great majority of these trials ended in failure, partly because of the scarcity of suitable beaches for seining, partly because the number of coarse fish taken per successful haul was too small to be of iimportance.

On the other hand, the conditions obtaining in Bass Lake are not altogether unique. Cahn (1929) reported upon the disappearance of vegetation and game fish from Neosha Mill Pond, in Wisconsin. When the pond was drained and seined, it contained 5,891 large carp, 81 Catostomidae, 7 bowfins, 17 white crappies, and 10 other game fish. Similarly Ricker (1932) examined an Ontario trout pond in 1928 that was almost barren of rooted vegetation, though there was evidence of a former abundance of *Chara*. Following removal of a large number of suckers (*Catostomus commersonnii*), the vegetation immediately began to reappear, and by 1930 formed a thick carpet over the entire pond. Possibly other examples are to be found in the literature. Whether or not a lake that has once succumbed to the domination of a sucking fish could in time revert to its former weedy state without human interference cannot be discovered from observations at hand. It would appear that the roiled and relatively barren condition is apt to be of some years' duration at least, even if not permanent.

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THE MIGRATION OF FISH FROM A SHALLOW TO A DEEP LAKE IN SPRING AND EARLY SUMMER

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ABSTRACT

A situation in which a rapidly warming lake is connected with a relatively cool lake is described. Three species of fish, whitefish, lake trout, and burbot, exhibited a definite migration from the warmer to the cooler lake, the larger fish leaving first. The number of catchable lake trout present in early spring in the warmer lake was determined and the concentration was found to be of the same order as that for other Canadian lakes.

INTRODUCTION

Among the many Algonquin Park lakes investigated by the Ontario Fisheries Research Laboratory, a particularly interesting combination was found. White and Big Trout Lakes present a rather unique situation in which a narrow channel connects a shallow lake with a deep lake (Fig. 1). In fact, White Lake might almost be considered as a bay of Big Trout Lake. In the spring, lake trout are known to migrate from White Lake through the connecting channel, and in most years angling shows they are completely absent from White Lake in midsummer. These circumstances led to an investigation of these lakes in 1939 with two purposes in mind: (1) to study the migration of various species; and (2) to count the number of lake trout present in a known area.

Big Trout Lake covers 3,630 acres and has a maximum depth of 95 feet. About 25 per cent of the total volume is more than 45 feet deep. White Lake has 1,040 acres of open water and is continuous with an additional 600 acres of swamp. The maximum depth is 45 feet, but only 10 per cent of the lake area is over 30 feet deep, and only half the total volume of water in the lake is over 10 feet deep.

Water entering White Lake must first pass through the marshy area. This area is so shallow that the water is rapidly warmed by the sun. The influx of heated water from this swamp causes White Lake to warm more rapidly than most lakes in the region. The course of this warming is shown in Figure 2 and in Table 1. Thus, by the middle of June, over 90 per cent of the bottom area and 97 per cent of the total volume was above 14° C. (57.2° F.). In Big Trout Lake, on the other hand, one-quarter of the total volume—representing one-

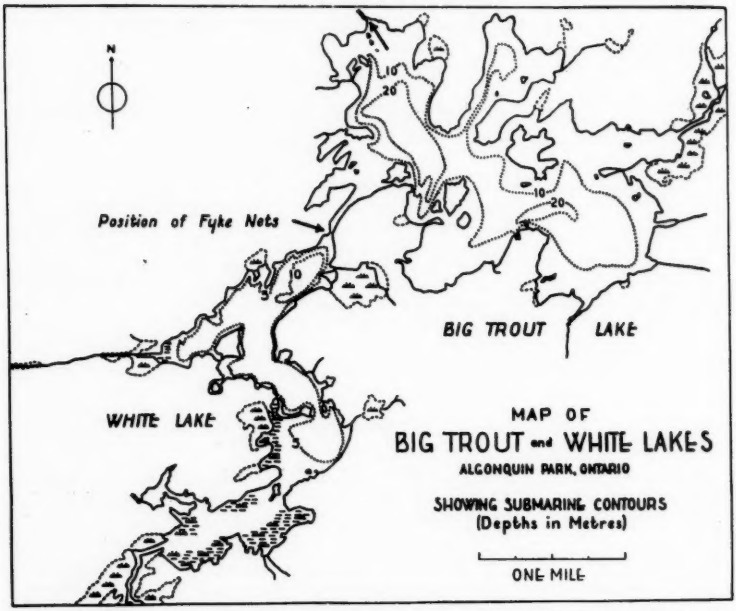

Figure 1.—Big Trout and White Lakes, Algonquin Park, Ontario, with depth contours and locations of fyke nets used in the migration study indicated.

third of the total area—was still at 13° C. (55.4° F.) on August 24th, by which time lakes in this region have reached their maximum temperatures for the year.

Table 1.—The rise in temperature in White Lake during 1939

Depth (feet)	Percentage of bottom area	Percentage of total volume	Average temperature (° C.)				
			May 9-16	May 17-30	May 31-June 13	June 14-27	June 28-July 11
0-10	19	51	9	12	17	18	21
10-20	45	37	9	10	16	17	19
20-30	27	12	8	9	14	16	17
30-40	5	3	?	8	10	12	13
40-45	4	+	?	?	8	9	9

Method of Study

Since the channel between the two lakes was only 100 feet wide and 12 feet deep, it was quite easy to record movements of fish from one lake to the other by catching them in fyke nets. On May 9, 1939

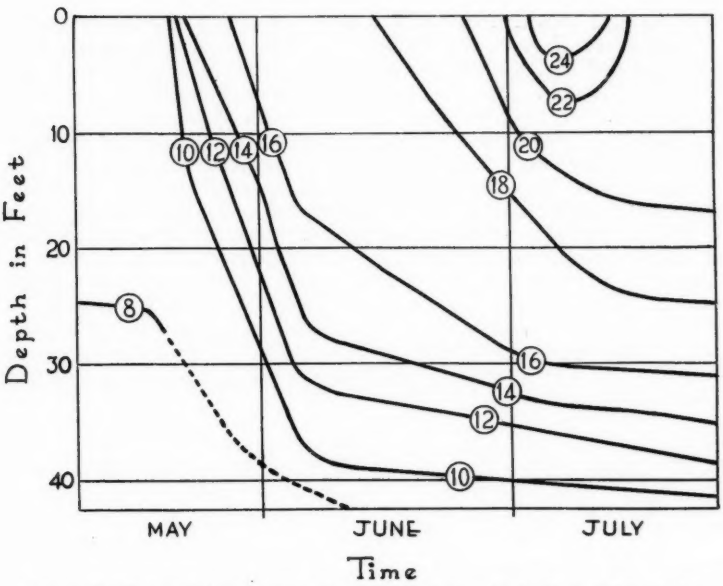

Figure 2.—Seasonal temperature changes in relation to depth in White Lake. (Isotherms in ° C.)

(5 days after the ice went out), a fyke net was set to completely block the channel in such a way as to catch fish leaving White Lake. This fyke net had a square-hooped pot with three throats, was 6 feet by 8 feet at the mouth, and was made of 2-inch stretched mesh. The wings of the net were of 3-inch and 4-inch stretched mesh.

On May 11, another fyke net was set about 50 yards nearer Big Trout Lake, completely blocking the channel, to catch fish attempting to enter White Lake. This net was round-hooped, 5 feet in diameter at the mouth, with two throats, the pot being of 2½-inch stretched mesh.

Both nets were fished continually until July 14, on which date both were pulled out. During the first week all the fish captured were retained. Later, most of them were released into the lake toward which they were moving.

Fish Movements

Whitefish, *Coregonus clupeaformis* (Mitchill); lake trout, *Cristivomer namaycush* (Walbaum); speckled trout, *Salvelinus fontinalis* (Mitchill); common suckers, *Catostomus commersonii* (Lacépède); fallfish, *Leucosomus corporalis* (Mitchill); brown bullhead, *Ameiurus*

nebulosus (LeSueur); an eel, *Anguilla bostoniensis* (LeSueur); yellow perch, *Perca flavescens* (Mitchill); sunfish, *Lepomis gibbosus* (Linnaeus); and burbot or ling, *Lota lota maculosa* (LeSueur) were captured in the nets. The total numbers of each species taken are shown in Table 2.

The movements of the common suckers and of the fallfish are probably related to spawning, since both species spawn in late May and early June. The numbers of yellow perch, brown bullheads, sunfish, eels and speckled trout were too small to indicate a definite migration, but the whitefish, lake trout, and burbot or ling showed a definite migration as the water warmed. This migration is summarized in Table 3.

Table 2.—The total numbers of fish which moved through the channel connecting White Lake and Big Trout Lake from May 10 to July 14, 1939

Species	Total fish leaving White Lake	Total fish entering White Lake
Whitefish	167	5
Lake trout	826	38
Speckled trout	1	1
Common sucker	5,294	1,887
Fallfish	234	63
Brown bullhead	22	6
Eel	1	0
Yellow perch	87	3
Pumpkinseed sunfish	12	0
Burbot	263	185

Table 3.—The seasonal change in numbers[1] and in average length in inches of three species of fish passing through the channel connecting White Lake and Big Trout Lake

Species	Direction of migration	Item	Dates				
			May 10-16	May 17-30	May 31-June 13	June 14-27	June 28-July 14
Whitefish	Leaving White Lake	Number[1]	21	30	28	8	7
		Average length	11.9	9.4	9.7	8.9	8.1
	Entering White Lake	Number[1]	1	1	0	1	0
		Average length	18	11.5	..	10	..
Lake trout	Leaving White Lake	Number[1]	130	132	144	70	10
		Average length	19.6	19.5	18.1	18.3	17.2
	Entering White Lake	Number[1]	16	10	0.5	1	0
		Average length	18.5	19.1	15	15	..
Burbot	Leaving White Lake	Number[1]	102	58	12	12	4
		Average length	24.3	21.6	20.0	17.2	17.0
	Entering White Lake	Number[1]	137	26	4	1	2
		Average length	23.7	22.2	15.6	21	18

[1]Refers to average number of fish caught per week during the time interval. See table 2 for actual totals.

Although a few lake trout entered White Lake, the general movement was obviously the other way. An average of 130 per week left from May 9 to May 16; 132 per week during the last half of May; and 144 per week during the first half of June. In the second half of June, the number emigrating dropped to 70 per week with a further decline to 10 per week in the first half of July.

The migration of whitefish was almost identical with that of lake trout, except that fewer fish were involved. Twenty per week left during the second week in May; 30 per week left during the last half of that month; and 28 per week during the first half of June. The number then fell to 8 and 7 per week, respectively, for late June and early July.

It should be noted that, whereas the lake trout taken represent most of the size range for the species, only the largest of the whitefish were taken in the nets. Supplementary fishing with a 1¼-inch (stretched mesh) gillnet indicated that, although whitefish smaller than those taken were migrating, large numbers of them were still left in White Lake at the time fishing was terminated.

The burbot, or ling, migration is more complex than that of the whitefish or lake trout. From May 9 to May 16, 137 burbot per week attempted to enter White Lake, while only 102 per week left. In the last half of May, however, the direction of migration was reversed, and 58 per week left, while only 26 per week attempted to enter. During June only 12 fish per week left White lake, and the movement in the other direction was still more negligible. In the first half of July only 4 burbot per week emigrated. Thus there is a continual diminution in numbers of burbot both entering and leaving White Lake. Superimposed on this fact is a tendency for burbot to enter White Lake during the first week of fishing, after which time they tended to leave.

One outstanding characteristic of the migration exhibited by each of the three species is the gradual decline in average length. As shown in Table 3, the average length of whitefish dropped from 11.9 to 8.1; that of lake trout from 19.6 to 17.2; and that of burbot from 24.3 to 17.0. In each species the larger fish migrated earlier than the smaller fish.

The Lake Nipissing ciscoes, *Leucichthys artedi* (LeSueur), in their annual migration from warm shallow water to colder deep water show a similar change in size composition, namely, the largest fish migrate first, followed by successively smaller size groups (Fry, 1937).

Productivity of Lake Trout

The number of lake trout taken decreased continuously after the middle of June. In fact, no lake trout were taken for 5 days previous to the time fishing was discontinued, and fishing with gill nets failed to take any lake trout in White Lake in July. These facts make it seem certain that no lake trout (or at least negligible numbers) were left in White Lake when fishing was discontinued. Hence, the number of lake trout in White Lake at the beginning of the season (assuming no deaths) must have been the number which came out less the number released alive into White Lake, 813. As there are 1,040 acres in White Lake, the total number represents a little less than one lake trout per acre.

Although the fish were not weighed directly, a consideration of the number of fish in each length group enables the total poundage to be calculated, since the customary or average weight of a lake trout of a given length is known. It is found that White Lake contained about 2 pounds of lake trout per acre when fishing was begun.

Data are now available on the lake trout populations of five Canadian lakes. The probable populations of Butler, Brewer, and Costello lakes have been reported previously (Fry, 1939). An estimate of the number of lake trout in Indian Lake, Quebec, is based on data (unpublished) obtained when practically all of the fish were netted from this lake under the direction of Professor W. J. K. Harkness. In each of these four lakes, as in White Lake, the population of lake trout was found to be roughly one fish or approximately 2 pounds per acre. The available data for all five lakes is summarized in Table 4.

Table 4.—Comparison of lake trout populations in five Canadian lakes

Lake	Location	Area (acres)	Fish per acre	Average weight (pounds)	Pounds per acre
Indian	Campeau Twp., Que.	520	0.5	2 to 3	1+
White	Algonquin Park, Ont.	1040	0.8	2.7	2.1
Costello	Algonquin Park, Ont.	100	0.9	....	....
Brewer	Algonquin Park, Ont.	100	0.9	....	....
Butler	Southworth Twp., Ont.	450	....	....	4.2

Acknowledgments

The investigation was conducted at the Ontario Fisheries Research Laboratory, University of Toronto, which is partially supported by the Ontario Department of Game and Fisheries. Professor W. J. K. Harkness and Dr. F. E. J. Fry, of the Laboratory, assisted with the investigation. The figures were prepared by Mr. J. Eliot. Mr. F. A. MacDougall, Superintendent of Algonquin Park, and Rangers P. J. Gervais and H. Haines cooperated during the field investigations.

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Discussion

Dr. A. G. Huntsman: If you have two rooms with a passage between them people may move between the two without any conscious idea of one being better than the other, but on the whole you will find them congregating in the more comfortable room. It would seem to be the same with fish; there does not seem to be any direct migration, but rather a random migration, with final concentration in the deeper and cooler lake.

TEMPERING VERSUS ACCLIMATION IN THE PLANTING OF SPECKLED TROUT

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Abstract

The acclimation of speckled trout, *Salvelinus fontinalis* (Mitchill), by keeping them in tanks at temperatures from 13° to 22° C. (55.4° to 71.6° F.) for a period of 12 hours raised the lethal temperature from 24° C. (75.2° F.) to 26° C. (78.8° F.). The lethal temperature was assumed to be that temperature at which 50 per cent of the fish die within a period of 14 hours (Hathaway's method).

Tempering speckled trout by gradually raising the temperature over a period of 15 minutes to that of the experimental tanks had no effect on the lethal temperature.

Introduction

Hatchery programs of planting speckled trout, *Salvelinus fontinalis* (Mitchill) often continue on into midsummer at a time when the temperature of the surface water of the lakes has reached a maximum. It is common practice to temper the fish in order to overcome the shock of sudden temperature changes which might otherwise prove fatal. Tempering is a process of gradually raising the temperature of the can containing the fish by dipping cold water out and warmer lake water back in, thus equalizing the tank and lake water temperatures. Experiments were carried out on yearling speckled trout to determine the value of such a practice.

Raising of lethal temperatures by acclimation of fish to progressively higher non-lethal temperatures has been done by Loeb and Wasteneys (1912), Hathaway (1927) and Sumner and Doudoroff (1939). Hathaway was able to shift the lethal temperature of black bass over a total range of 8° C. (46.4° F.). The fact that the temperature at which fish die can be raised suggested that such a procedure might be followed with hatchery fish, thus extending the period for which they may be safely planted during the summer.

Method

Throughout the month of June and on into July speckled trout were transported in large, iced tanks by truck from the Petawawa Hatchery near Pembroke, Ontario, to a series of three spring-fed troughs near Cache Lake, Algonquin Park, Ontario. Approximately 2,500 fish were carried per load, these being evenly distributed in the three troughs. From this point loads of from 300 to 700 fish were shipped to the individual lakes. For those lakes which were not accessible by truck,

pack cans were used and in some instances the fish were flown to the given locality. The former method was used in shipping trout for experimental work.

The procedure in the laboratory was simple. Tanks of dimensions 2 feet by 2 feet by 7 inches, coated inside with aluminum paint were heated with Bunsen burners. The flame of the burner was directed onto a sheet of galvanized iron, 2 inches below the tank, thus distributing the heat evenly over the bottom. The burners were regulated to give the desired temperature, which was maintained throughout the experiment. Each experiment lasted for 14 hours. Air was bubbled into the four tanks. From the pack can eight fish were put directly into a tank and the time of death for a given fish recorded, assuming that after a period of 14 hours, all fish that were still living would continue to do so or at least would not die from direct temperature effects.

In the process of acclimation, instead of putting the fish immediately into the heated tanks, they were first put into auxiliary troughs with running water regulated to the necessary temperature and kept there for 12 hours. If any fish died during acclimation, especially at higher temperatures, the experiment was discarded, thus avoiding selection. In acclimating to temperatures bordering on a lethal limit, stages at lower temperatures lasting for approximately 6 hours were followed through, after which time the trout were kept over night at a lower temperature. Consideration of a possible program for hatchery purposes was accordingly taken into account.

In the experiments on tempering, eight speckled trout were put in a large, glass, iced container at 10° C. (50° F.) and set in one of the heated tanks previously described. The customary system of dipping cold water out and warm water back in was followed. The exchange of water was continued over a period of 15 minutes at a rate which gradually raised the container temperature of 10° C. (50° F.) to that of the tank temperature (22 to 26° C., or 71.6 to 78.8° F.). The contents of the glass jar were then poured into the tank and the experiment carried out as usual.

The results have been plotted by two different methods. The first, in Figure 1, is that used by Hathaway (1927) in which the percentage of fish dead after 14 hours is plotted against temperature for a series of different critical temperatures. The second method, Figure 2, is that of Loeb and Wasteneys (1912). In the latter the y axis is not determined by the percentage that survived longer than 14 hours, but by averaging the time that all fish live, plus those that continue to survive beyond 14 hours, which are assigned a survival time of 14 hours. Hathaway's method provides a single, fixed index of comparison, the lethal temperature, and from this standpoint alone it is to be preferred to the method of Loeb and Wasteneys. The latter method best describes the data, however, since the actual time of death for each fish is utilized.

Results

Figures 1 and 2 show the results obtained from over 100 untreated yearling speckled trout taken directly from troughs at Cache Lake. Not less than 32 fish were used per experiment and 8 or more for each point. The temperature of the troughs averaged 11° C. (51.8° F.) and reached a maximum of 13° C. (55.4° F.). The lethal temperature was found to be 24.0° C. or 75.2° F. (Fig. 1, right.) Using this curve as a standard, the results of tempered fish are seen plotted in Figure 1 (left), and Figure 2. No change in the resistance of the fish to withstand the different temperatures was obtained.

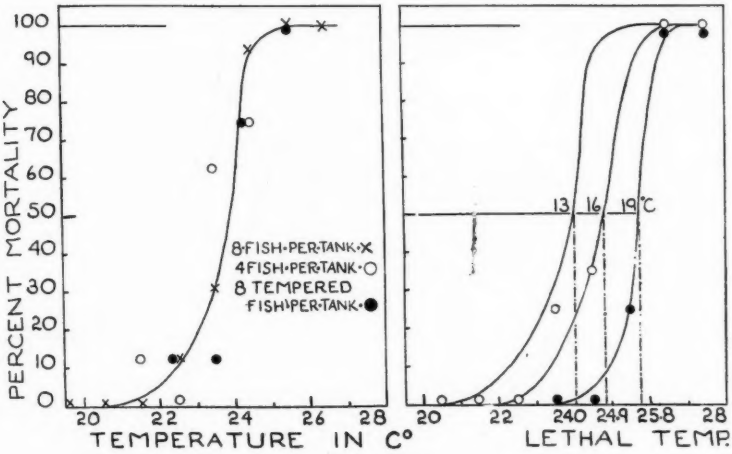

Figure 1.—Left, curve of percentage survival, for different temperatures, of yearling speckled trout acclimated at 13° C. (55.4° F.). Right—curve of percentage survival, for different temperatures, of yearling speckled trout acclimated at 13° C. (55.4° F.), 16° C. (60.8° F.), and 19° C. (66.2° F.).

Acclimation at 16 and 19° C. (60.8 and 66.2° F.) for 12 hours raised the lethal temperature to 24.9 and 25.8° C. (77 and 78.7° F.), respectively, that is, 0.9 and 1.8° C. above that for 13° C. (55.4° F.) acclimated fish. In efforts to acclimate the trout to temperatures of such a height as to be lethal for untreated fish some mortality ensued. The results of one experiment where no selection occurred are seen in Figure 2 for 22° C. (71.6° F.) acclimated fish. Apparently, for such short periods of acclimation the limit had been reached.

Care was taken to be sure that oxygen deficiency was not an interfering factor. Samples of the water were taken at regular intervals

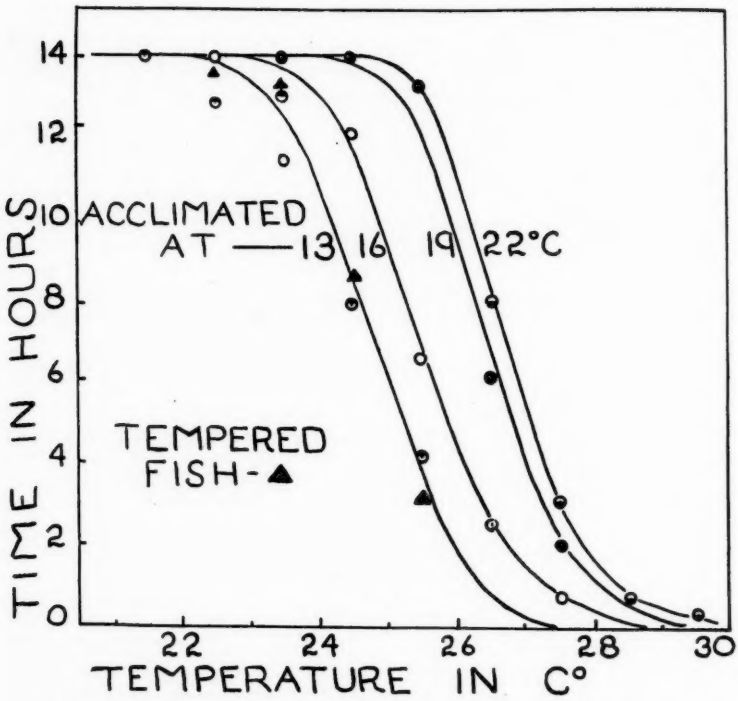

Figure 2.—Mortality curve of yearling speckled trout acclimated at different temperatures.

and the oxygen content determined by the Winkler method of analysis. At times the oxygen content was as low as 62 per cent of saturation, even with the aeration system in operation. Experiments were performed using 4 fish instead of 8 per tank. Here, the oxygen was 80 per cent of saturation and more. These results showed no appreciable difference (Figure 1, left).

Discussion

As stated previously, the experiments were carried out over a period of 14 hours. Hathaway (1927) has shown that in the case of the black bass the extent of the mortality, if present in such an experiment, is practically negligible after 14 hours. Corroborative evidence was obtained for speckled trout by performing an experiment over 24

hours at the lethal temperature of fish acclimated at 13° C. (55.4° F.). Out of 32 fish, 2 died after the fourteenth hour, carrying the percentage survival down from 50.0 to 43.7 by the twenty-fourth hour, a 6.3 per cent difference.

The reasons for choosing 12 hours as the length of time for acclimation were, (1) a possible practical time for hatchery purposes and, (2) the fact that the greater part of the acclimation effect has been found to be complete within the first day (Hathaway). In addition to these reasons an appreciable effect of acclimation was obtained by that length of time when experimenting with speckled trout. As previously pointed out the lethal temperature was raised by 2° C. for a change in acclimation temperature of 6° C. (13° C. to 19° C.).

At comparatively high temperatures (in the region of 21° C. or 69.8° F.) no fish die as a direct result of temperature within the 14 hours, but in all probability the resistance of the fish is weakened so that over a period of days death may result from disease or other adverse conditions, indirectly brought about by a high but subcritical temperature. For fish acclimated at 13° C. (55.4° F.) a danger zone has been reached at 21° C. (69.8° F.).

A factor that must be considered is the tendency of fish to seek lower levels in a lake and consequent lower temperatures. Doubtless this does occur, either intentionally or by chance, where the locality of planting is sufficiently deep. Very often no opportunity for seeking cooler waters presents itself when plantings are made near the shore as the depth is not great enough to provide a temperature variation and cool, deep water may not be within an easily traversed distance. On one occasion when planting fish in a shallow inlet of Opeongo Lake, Algonquin Park, where the temperature was 19° C. (66.2° F.), the fish were observed to remain close to shore for over 2 days, although deep water was near at hand. The inadvisability of planting fish in water of high temperature is evident since fish do not necessarily migrate to a depth where the temperature is more suitable.

During the summer of 1940 the surface temperature of Lake Opeongo rose from 18° C. (64.4° F.) on July 16 to 24° C. (75.2° F.) by July 23, and fluctuated by a few degrees until the fourth week of August when it dropped to 17° C. (62.6° F.). At one part of the lake in open water on August 18 when the surface temperature was 23.3° C. (74° F.) the temperature at 17 feet was as high as 21.0° C. (69.8° F.) and therefore still critical.

The type of curve plotted in Figure 2 is used for the reason that it affords a clearer conception of the progress of mortality than does a percentage survival curve like Figure 1. The latter gives no distinction between cases in which, either all fish die by the end of 14 hours, or the same number of fish die from tanks at two different temperatures. Thus as the curve approaches the 14-hour line it does not indicate an actual average time of death but rather the probability that a small percentage of the fish will die before 14 hours have elapsed.

Such a system of plotting is valuable for a comparative consideration of mortality curves for fish from different conditions. It also gives an opportunity to draw a curve as in the fish acclimated at 22° C. (71.6° F.) where there was complete mortality (Figure 2).

The temperature at which the trout begin to die is brought out equally well by both these curves. This temperature is the most significant of all. It is the critical temperature and might therefore be defined as the upper limit for planting purposes. Consequently it is not the lethal temperature that must be considered but this lower, critical temperature where the question of survival of the fish becomes uncertain. Figures 1 and 2 show that for fish acclimated at 13° C. (55.4° F.) 21° C. (69.8° F.) is critical, for fish acclimated at 16° C. (60.8° F.), 23° C. (73.4° F.) is critical, and for fish acclimated at 19° C. (66.2° F.), 24° C. (75.2° F.) is critical. Thus, acclimation raised the critical temperature of speckled trout by 3° C. (5.4° F.).

Figure 3 shows the rate of mortality at various temperatures and the rate for fish differently acclimated. Where the curve does not meet the 14-hour line there is no question as to the likelihood of a given fish surviving. There is 100 per cent mortality. A curve drawn through these points gives a complete picture. On the other hand at lower temperatures a degree of uncertainty arises where only one or two fish die. The survival or death of a single fish makes a marked difference in the curve. The same fact is seen in Figure 1, right, in so far as the relative extent of scattering of points near the bottom of the curve indicates a greater degree of uncertainty. The problem is readily solved by using a comparatively large number of fish for these

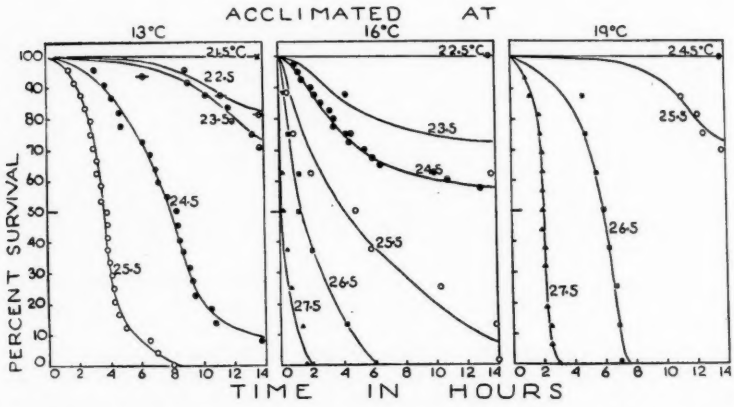

Figure 3.—Progressive rate of mortality of yearling speckled trout at given temperatures for three different temperatures of acclimation.

lower temperatures. This uncertainty also accounts for the type of curve which is sigmoid. At 21° C. (69.8° F.) where the temperature becomes critical for fish acclimated at 13° C. (55.4° F.) there is always the possibility of a fish dying, and conversely at the other end of the curve the fish are sure to last for some time if only a fraction of a minute.

Conclusions

The foregoing experiments show that there is no advantage to be gained by tempering yearling speckled trout.

The lethal temperature of the trout from 13° C. troughs can be raised approximately 2° C. by acclimation for 12 hours at 19° C. and the critical temperature raised 3° C. These lethal temperature experiments were carried out on the following day, subsequent to keeping the fish at 13° C. during the night. It might therefore prove profitable in planting speckled trout to hold them at 19° C. throughout the day previous to liberating them in lake water of temperature as high as 23° C.

In Lake Opeongo the surface temperature rose to 21° C. by July 19, 1940, which was critical for untreated fish but not for those acclimated at 19° C. Thus the benefit of acclimation is clearly indicated.

Acknowledgments

The author acknowledges his indebtedness for the suggestions and assistance rendered by Dr. F. E. J. Fry, Dr. E. C. Black, and Prof. W. J. K. Harkness during the investigation and in the preparation of the manuscript.

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FURTHER DEVELOPMENTS OF THE ELECTRICAL METHOD OF COLLECTING FISH

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ABSTRACT

Developments presented include changes in technique, which extend the scope of the method to streams 40 to 60 feet in width; and modifications of the equipment to increase the safety of the operators. Projects to which the electric shock method has been applied are reviewed briefly. Recovery tests are reported in streams of widely varying character.

INTRODUCTION

The electric shock method of stream census was developed in 1939 and was described previously by Haskell (1939). To avoid repetition it will be assumed that the reader is already familiar with that paper.

For the 1940 season a unit of five men was organized to apply the electrical method of collecting fish to practical problems. In cooperation with the New York State Bureau of Biological Survey, a list of streams was selected in which special problems existed.

The variety, both in size and type, of the streams made possible a thorough test of the scope and limitations of the method and led to studies whereby the use of the device might be extended to larger streams.

TECHNIQUE

From the tests made in 1939, it was concluded that the electric shock apparatus was adapted for use in streams not more than 20 feet wide nor more than 3 feet deep. The work in 1940 furnishes a better knowledge of these limits. Streams in New York State fall into four general classes insofar as the electrical census method is concerned:

1. Soft water with clay, or sand and clay soil having low electrical resistance.—In the electrical circuit employed by the shock apparatus it is important to have the major voltage drop in the water. Therefore, the combination of low-resistance soil and high-resistance water is ideal. This type of stream is found scattered throughout the State, but is particularly common in the foothills of the Adirondacks.

2. Soft water with rocky, sandy, high-resistance soil.—This condition, found chiefly in Adirondack streams causes the voltage to divide between water and soil and some effectiveness is lost. Several ground bars spaced a few feet apart provide a satisfactory remedy.

3. Hard water with low-resistance soil.—This combination, which is found scattered throughout the State, works well but has the possible disadvantage of drawing a heavy current from the generator so

that the generator capacity may be exceeded. In the streams where the apparatus has been used, none has required so much current that the 500-watt generator would not supply it with an electrode 12 to 15 feet long. A screen of this length would usually be ample for streams 20 feet wide.

4. *Hard water with rocky, sandy, high-resistance soil.*—This type is fairly common particularly in upland streams. It presents real difficulty, since even a large number of ground bars will not reduce the voltage drop in the soil to a low value. To overcome this condition a new technique has been developed. The screen electrode is used as before but no ground bars are used. To the ends of a bare flexible wire equal in length to the electrode, insulated handles are fastened and the generator terminal formerly connected to the ground bars is connected to this wire by a long, flexible lead. The bare wire is dragged on the bottom of the stream 4 to 6 feet behind the electrode. The electric current passes from the screen electrode through the water to the bare wire. This method greatly increases the effectiveness of the shock so that somewhat lower voltages may be used than with ground bars. In hard water with poor ground conditions it seems to be the only solution. The principal disadvantages of the method are that it requires additional help to pull the bare wire, and that it is somewhat slower to operate.

Since, with the bare wire instead of ground bars, there is no voltage loss in the ground, the length of the screen and bare wire may be increased until the current capacity of the generator is reached. In order to utilize this method in large streams a 5-kilowatt 110/220-volt alternating-current generator has been acquired, which will operate successfully in streams 60 feet in width.

Safety Precautions

The possibility of serious electric shock to the operators has been a matter of continual concern in the use of the electric shock apparatus. Competent authorities on the physiological effects of electric shock have been consulted, and they state that the electric field in the water is such that were a man placed in the water under the electrode the shock might be fatal. This point is important since it shows that the apparatus is dangerous if improperly handled.

A major precaution for the safety of the crew is proper supervision. The apparatus should not be operated except under the direction of an electrical engineer or physicist or a person who has thoroughly familiarized himself with the apparatus.

Rubber boots or waders for all operators are essential although it is almost unnecessary to mention this precaution since one cannot approach the electrode in the water without receiving a warning shock if boots are not worn. The men handling the electrode should wear rubber gloves.

The principal remaining hazard is that someone will fall in the stream near the electrode. To minimize this danger a device has been provided to break the circuit quickly at the handle of the electrode. The wire bringing current to the electrode is fastened at the top of the handle and runs down to the screen. The wire has been cut at the top of the handle and a plug, similar to that used for a domestic electric outlet, attached to the free end coming from the generator. The female complement of this plug, called a "pony connector body" is fastened rigidly to the handle and to it is connected the wire from the screen . The operator may break the circuit quickly by removing the plug. This arrangement is not entirely satisfactory. Some sort of switch which opens automatically when the operator releases his grip on the handle would afford greater protection.

In soils where it is difficult to secure a satisfactory ground connection, such as Type 2 discussed under "Technique," another shock hazard exists because a voltage loss occurs in the soil. Thus, a voltage difference is present between the soil at a point away from the ground bars and the wire connecting the bars to the generator. Although the voltage difference is small a person or an animal, standing on the soil, would receive a shock if he touched the wire connecting the bars. To remove this danger insulated wire is used to connect the ground bars and the tops of the bars are covered with pieces of 2½-inch rubber hose.

The foregoing discussion of safety measures is purposely pessimistic and has emphasized the dangers, since human life is involved. In 2 years of operation no one has received any appreciable shock. When carefully used the apparatus may be considered safe.

Problems Studied

A brief review of a few of the simpler problems to which the electric shock apparatus has been applied will illustrate the various uses to which it may be put.

Bass removal from trout streams.—Schoharie Creek was once a trout stream but is now heavily populated with smallmouth black bass, *Micropterus dolomieu*. It was desired to remove the smallmouth bass population above a newly constructed barrier dam, in order to improve trout fishing and to provide smallmouth black bass for restocking purposes. Various netting methods having proved unsuccessful because of a rocky, uneven bottom, tests were made with the electric shock method. An average of 120 smallmouth bass, 4 to 12 inches in length were removed daily. The operating cost was approximately $37.50 per day.

In the Genesee River the comparative efficiency of removing bass by the electric method and by seining was tested. It was found that in this stream about 250 smallmouth bass could be removed per day by either method. The cost of the two methods was nearly equal. A dis-

advantage of the electric method was the greater amount of equipment required, which prevented economical operation where there was no road adjacent to the stream. The population of smallmouth bass in the stream was estimated by means of the electrical census method to be about 500 per mile.

Population studies.—In connection with the purchase of fishing rights on Kayaderosseras Creek, the question arose whether large trout migrated down into the lower unstocked section of the stream and maintained themselves in sufficient numbers to justify purchase. Reports from fishermen were conflicting. Three typical sections totaling one-quarter mile were sampled by the electric method, and only two trout between 7 and 8 inches in length were captured. Large wall-eyed pike, *Stizostedion vitrum,* and smallmouth black bass, *Micropterus dolomieu,* were present in considerable numbers. It was concluded that the section was unimportant for trout.

A study of the effects of planting ulcerated brook trout, *Salvelinus fontinalis fontinalis* was made in Cold Spring Brook, a small stream 0.6 mile in length. One hundred 5-inch ulcerated brook trout were planted in the winter of 1939. Four months later an electric census showed the presence of none of the planted fish, and no symptom of the disease was observed on any of the native population. Subsequent censuses emphasized these findings. A planting of healthy brook trout in the winter of 1940 was used as a check against the preceding year's results. Four months after planting 50 of these fish were recovered, with a tested efficiency of 85 per cent. This indicates a survival of 59 of the 100 fish. Another census 2 months later showed a survival of 38 of the original 100 fish. It was concluded that the ulcerated fish died soon after planting, and that the disease was not transmitted to the brook, brown and rainbow trout resident in the stream at the time of the planting.

Recovery Tests

In making population studies an estimate must be made of the completeness of the collection. Theoretically, in order to test a method, one should block off a section of stream, make a population study and then, by some means, such as drying up the stream, collect every fish left in the section and calculate the recovery.

Due to the immense difficulty of such a procedure a more common way of determining the percentage recovery is to plant marked fish before beginning the population study. This method involves many objectionable features; for example, if hatchery fish are used one might expect them to be easier to capture than the fish native to the section. Similarly, native fish marked and planted in the section from which they were taken or in another section, might be easier to collect than undisturbed native fish. With these difficulties in mind a number of recovery tests have been made, each of which is open to criticism on one or more points.

Tests were made in two sections of Cascadilla Creek using 4½-inch hatchery brown trout, *Salmo fario*. Each section was 200 feet long, 20 feet wide and 10 inches deep and was composed of riffles with a rubble bottom. For each test, five lots of 10 trout each, were marked individually by clipping a fin. Five lots were planted at the same time between blocking nets and left 15 minutes before electric shock was induced. In the first section recoveries of the five groups were, respectively, 10, 10, 10, 9, 9. In the second section the recoveries were again 10, 10, 10, 9, 9. The total recovery for each section was 96 per cent with a range in the five groups from 90 to 100 per cent.

Similar tests were made in two sections of Fortsville Brook using five groups of marked native brown trout ranging in length from 4 to 11 inches. The sections were about 250 feet long, 13 feet wide and 17 inches deep; and consisted mainly of pools with a sand and clay bottom. The total recovery in the first section was 96 per cent and for the five groups ranged from 90 to 100 per cent. In the second section the total recovery was 98 per cent and the groups ranged from 90 to 100 per cent.

Coincident with the above tests in Fortsville Brook, five groups of 3-inch marked hatchery brook trout, *Salvelinus fontinalis fontinalis,* were planted in each of the sections. In the first section the total recovery was 41 per cent with a range of 30 to 60 per cent. In the second the total recovery was 66 per cent with a range of 50 to 90 per cent.

Two test sections of Wiscoy Creek were about 400 feet long, 40 feet wide and 2½ feet deep. They were composed of pools and riffles with a rubble and gravel bottom. Native brown trout from 6 to 9 inches long were used in groups of 10 with only one group per section. Recoveries were 90 and 100 per cent, respectively.

Five tests were made in East Koy Creek in sections about 350 feet long, widths ranging from 7 to 30 feet, and depths from 6 to 24 inches. The fish were native brown trout from 4 to 9 inches long. Recoveries ranged from 90 to 100 per cent. One test was made with native rainbow trout, *Salmo gairdnerii irideus,* from 4 to 8 inches long with a recovery of 80 per cent on a group of five fish.

A section of Trout Brook was 400 feet long, 15 feet wide and 10 inches deep; and was composed of riffles with a rubble and gravel bottom. Native brown trout 6 to 7½ inches long were used. The recovery of a group of five fish was 100 per cent. From a group of native brook trout fingerlings 3 inches long, which were planted at the same time 60 per cent were recovered.

The results of the tests may be divided into two groups. All recoveries with trout more than 4 inches long were 80 per cent or greater. The heterogenity of test conditions shows that, for fish in this size group, width of stream, depth of water, type of section, and type of bottom do not have an important effect on recovery.

On the other hand the recovery of fingerlings is highly variable.

Not only does the recovery vary from section to section but even in a particular section the recoveries of different groups vary widely.

From these data it appears that the electric shock method furnishes a good qualitative and quantitative measure of populations of large trout, while for fingerlings, the sampling variability is so large that only qualitative information may be obtained.

Acknowledgments

The authors wish to express appreciation to Sumner M. Cowden, Superintendent of Fish Culture, New York Conservation Department, who suggested the bare wire for a ground connection; and to Howard M. Jenkins, Associate Professor of Electrical Engineering, Swarthmore College, for advice in regard to the physiological effects of electric shock.

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CATCHES OF SPECKLED TROUT FROM THE PLANTINGS OF HATCHERY-RAISED FISH IN PRIVATE WATERS OF ONTARIO

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ABSTRACT

Records have been kept for a number of years of plantings and catches of speckled trout in three small privately-controlled lakes in Ontario. These records are presented which have afforded information on productivity and magnitude of the populations.

INTRODUCTION

During the last few years there has been a growing interest in the results from the planting of hatchery-raised fish of various species in natural waters. It is difficult to obtain positive information on the returns from plantings of hatchery fish and the difficulty increases proportionately with the size of the body of water. There has been some increase in the amount of data available on this general subject and any authentic additional information is of value to those interested in evaluating the practical effects of fish culture.

The three bodies of water considered herein are small in area but, since fairly large numbers of fish are involved and the data are known to be quite accurate, it is believed that the information that has been secured is worthy of record.

The fish considered were not fed artificially at any time in any of the lakes or ponds so that natural conditions with respect to food supply are represented. All lakes and ponds considered are carefully screened so that there are no losses from or additions to the fish populations through migration.

Unless otherwise specified, all trout mentioned in this paper are speckled trout (eastern brook trout), *Salvelinus fontinalis* (Mitchill).

All of the information presented has been obtained from the records of Mr. Herbert E. Pearen, Mr. Philip Tidy and Mr. Garnet Bell, secretary of the Glen Major Club. It is with pleasure that I acknowledge the assistance of these gentlemen and their untiring energy in maintaining their records.

PEAREN'S LAKE

At Shadowbrook, Hornings Mills, Ontario, Mr. Herbert E. Pearen created an artificial lake by damming the headwaters of a small trout stream fed by springs. The dam creating the lake was constructed in 1931 and the surface area of the impoundment increased in size in 1933. The lake resulting from the original dam had an area of 8 acres

and a maximum depth of 9 feet which was increased through the addition to the dam in 1933, to an area of 11 acres with a maximum depth of 14 feet. The flow over the dam is approximately 2¼ cubic feet per second.

There were numbers of trout in the stream at the time the dam was constructed, which trout appear in the 1932 catch. There are no other species of fish in the lake.

When the lake filled in the fall of 1932, *Chara* was planted. It spread throughout the lake so that now the whole bottom is covered with the plant.

Mr. Pearen operates a hatchery in conjunction with the lake and takes spawn from all of the fish which come to the spawning area so that it may be assumed that re-stocking by naturally deposited spawn is negligible.

The data covering planting and catches are incorporated in Table 1. It may be noted that the average run of trout is from 8 to 12 inches in length, which is typical of the *Chara* producing lakes of the limestone area of Ontario, in the absence of forage fish. These lakes typically produce large numbers of medium-sized trout but few trout of very large size. In August, 1938, a trout weighing 3 pounds 3 ounces was taken from Pearen's Lake.

Table 1.—Artificial stocking with speckled trout and catch returns from Pearen's Lake, Hornings Mills, Ontario, a controlled fishery in an artificial lake constructed in 1931

Year	Planting (1-inch fingerlings unless indicated otherwise)	Catch						Estimated total population (November)
		Number	Length range (inches)	Number per pound	Number per acre	Pounds per acre	Number artificially spawned[1]	
1932	50,000 (Apr.)	[2]300	.....	..	....	....	.....	.....
1933	None	1,866	7- 8½	7	233	33	.....	.....
1934	None	1,600	8- 9	3	145	48	.....	.....
1935	28,000 (Apr.) 8,000 (Aug.)	1,867	8-11	2	170	85	.....	.....
1936	50,000	2,000	8-12	2	182	91	.....	.....
1937	80,000	5,500	8-12	2	500	250	.....	.....
1938	125,000 (1½-inch)	3,300	8-12	2	300	150	1,536 females 2,806 males	.....
1939	None	1,780	8-12	2	162	81	2,509 females 3,329 males	8,000
1940	75,000 (May) (2-inch)	2,506	8-12	2½	228	91	1,344 females 1,642 males	.....

[1]From 1936 to 1937 between 500,000 and 750,000 eggs were spawned each year from the fish in the lake.
[2]From original stock in the stream.

Glen Major Ponds

At Glen Major, Ontario, a series of three ponds with a total area of 8 acres and a maximum depth of 14 feet have been operated by a trout club for many years. They were originally formed by dams, constructed probably in the 1880's as a source of water power for the operation of a mill and they undoubtedly produced trout for many years before the beginning of this record.

These ponds in the limestone area of Ontario contain vast quantities of *Chara* which grows in such profusion that at times it reaches the

surface in parts of the ponds. The only other fish present in these waters are a few sculpins (*Cottus* sp.) which are not common (Ricker, 1933).

Short tributary streams feed the ponds and there is known to be some spawning at the mouths of these streams. Spawning areas are limited and do not appear to be particularly favorable and it is believed that the supply of catchable fish is not greatly augmented in this manner. The data for the planting and catches for this series of ponds are included in Tables 2 and 3.

Table 2.—Plantings and catches of speckled trout in Glen Major Ponds, Glen Major, Ontario; a controlled trout fishery in a series of artificial ponds

	Plantings		Catch		
Year	Number	Length (inches)	Number	Number per acre	Pounds per acre
1902	.....	.....	1,058	132	66
1903	.....	.....	987	123	60
1904	.....	.....	960	120	60
1905	.....	.....	952	119	60
1906	.....	.....	652	82	41
1907	.....	.....	893	112	56
1908	.....	.....	1,109	139	69
1909	.....	.....	1,013	126	63
1910	.....	.....	1,013	126	63
1911	.....	.....	1,117	139	69
1912	.....	.....	828	103	51
1913	.....	.....	737	92	46
1917	.....	.....	847	106	53
1918	.....	.....	985	123	61
1919	.....	.....	1,011	126	63
1920	.....	.....	1,248	156	78
1921	.....	.....	941	118	59
1922	.....	.....	1,194	149	74
1923	.....	.....	912	114	57
1924	.....	.....	985	123	61
1925	.....	.....	1,164	145	71
1926	.....	.....	1,145	143	71
1927	.....	.....	1,108	139	69
1928	.....	.....	1,134	141	70
1929	.....	.....	916	115	57
1930	20,000	Fry	1,027	128	64
	500	4-5			
	5,000	2-3	.....	.....	....
1931	2,000	4-5	1,218	152	71
1932	1,000	6-9	1,446	180	90
1933	1,000	6-10	1,238	154	77
1934	7,000	3-5	858	107	53
1935	.....	.....	1,170	146	73
1936	3,000	2-3	1,864	233	116
	2,000	4-6			
1937	1,000	4-5	1,710	213	106
	2,000	5-8			
1938	1,000	5	1,812	226	113
1939	1,500	5	1,451	181	90
1940	3,200	5-7	1,195	149	74

Table 3.—Plantings and catches of rainbow trout in Glen Major, included in the totals of Table 2

	Planting			Catch (Number)
Year	Number	Length (inches)	Month	
1936	900	6-10	June	....
1937	.....	.....	.....	17
1938	1,000	6	Oct.	13
1939	500	5	Sept.	114
1940	.....	.....	.....	113

The numbers of fry planted each year prior to 1913 are unknown. From 1914 to 1929 an average of 5,000 3- to 5-inch fingerlings were planted each year in October, according to Mr. Garnet Bell, although Ricker (1932) stated that 8,000 fingerlings were planted each year. Plantings in 1930 were in May and October; in 1931 to 1933, in May; and in 1934 to 1940 in September and October. The lengths of fish caught average from 7 to 12 inches, the average individual weight was about 8 ounces, and the maximum individual weight 2½ pounds.

Tidy's Lake

At High Lakes, Mono Centre, Ontario, Mr. Philip Tidy purchased a lake in 1937. It is about 5 acres in area with a maximum depth of 35 feet and has a considerable area of water with a depth of 28 feet. It also is in a limestone area with a natural growth of *Chara*. When first examined there were no fish in it. There are no tributary streams in Tidy's Lake and if natural reproduction occurs, fish produced in this way have probably not entered into the fishery to any appreciable extent. The data of plantings and catches are recorded in Table 4.

Table 4.—Plantings and catch returns of speckled trout from Tidy's Lake, Mono Centre, Ontario[1]

	Planting			Catch		
Year	Month	Number	Length (inches)	Number	Length (inches)	Maximum weight (pounds)
1937	Sept.	750	3-5	.....	.....	.....
1938	Sept.	1,000	3-5	181	8-13	1
1939	.....	.....	.....	369	10-11	1½
1940	May	1,000	2-4	74	.....	.....

[1]In October, 1938, 2 brown trout (*Salmo trutta*) were planted; in June, 1939, 1 brown trout was caught.

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Discussion

Mr. Marshall: Could there be any stocking of these lakes with forage fish?

Mr. Harkness: In most situations the people who are operating the controlled fisheries prefer to produce a large number of fish 8 to 12 inches long rather than a few fish of larger size. Wherever larger fish do occur they make an effort to remove them, because they destroy large numbers of the smaller fish. Larger fish can be grown in these controlled fisheries, but it would occur at the expense of numbers of smaller ones, which are of a desirable size—8 to 12 inches long.

Dr. Vladykov: You mentioned a catch of 500 to the acre from Pearen's Lake after a planting in 1937. On what basis was this figure calculated?

Mr. Harkness: The actual number of fish caught is determined. All the fishing is conducted from one boat house, and the fish are counted as they are brought in, so that the numbers given here are absolutely maxima. He knows that a few have got away with fish that were not recorded, but not very many.

THE EFFECT OF INCREASING THE STOCK IN A LAKE ON THE SIZE AND CONDITION OF RAINBOW TROUT

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Abstract

An investigation of the changes in length, weight and the length-weight relationship of rainbow trout from Paul Lake, British Columbia, is presented. As a result of the management policy adopted in 1931 the stock in the lake increased from 1932 to 1935; at the same time both the length and weight decreased significantly as evidenced by representative samples of yearling and 2-year old fish. A valid method of comparing the length-weight relationship is presented. The findings indicate that, although significant fluctuations occurred, and there was a significant decrease in the condition of the first fish planted when they reached 2 years of age, the factors involved require further study. A recommendation for modifying the stocking policy for depleted waters is given.

Introduction

The writer reported (Mottley, 1940) that the estimated yield of rainbow trout, *Salmo gairdnerii*, from Paul Lake, British Columbia, had increased, under the stocking policy that was adopted in 1931, from 3,000 fish in 1932 to 12,000 fish in 1935. Additional evidence, such as the catch per boat-day and the increase in the number of fish in the spawning run, was also given as an indication of an increase from the original depleted condition which had already been reported (Mottley, 1932). It was found, however, that the average weight of the fish had dropped from 1.5 pounds in 1932 to 1.0 pound in 1935. It is a matter of some interest, therefore, to find out if this decrease in weight was accompanied by a change in the "condition" of the fish.

Apparently no one has determined what is meant by "good" or "poor" condition of fish, but fishery biologists usually make comparisons on the basis of a coefficient of condition or "condition factor" derived by dividing the weight of an individual by the cube of its length and multiplying the result by a constant which is determined by the units in which the original measurements are taken. There are a number of reasons why the coefficient of condition so calculated, is of little value for comparing the condition of individuals or groups of fish. In the first place it is assumed on *a priori* grounds that the length-weight relationship of all the individuals of a group follows the "cube law." The use of regression methods surmounts this difficulty by supplying an estimate of the relationship or "law" for each group from the internal evidence of the situation. In the second place the calculation of the coefficient of condition does not permit an efficient estimation of variability, hence adequate tests of significance cannot be applied. Finally, there is a curvilinear relationship between length

and weight and the data must be rectified by transforming them to logarithms before direct comparisons between fish of different lengths can be made. All of the difficulties can be overcome by the use of the analysis of covariance as described by Snedecor (1940).

By means of the analysis of covariance of the logarithms of length and weight the data can be reduced so that efficient comparisons between groups can be made. The method consists, briefly stated, in the adjustment of the mean weight of different groups to an average length as a standard of comparison. In the present problem the fish may have decreased in length as well as weight from 1932 to 1935 and the analysis of covariance will permit a valid comparison of the weights after making due allowance for any concomitant change in length. The whole procedure reduces the weight of all individuals to a standard or average length, then it can be judged whether the group is heavier or lighter than would be expected on the basis of normal variation. From this it may be inferred that a group of relatively heavy fish is in good condition; whereas a group of relatively light fish is in poor condition.

The Problem and the Possible Solution

The problem is two-fold and may be stated thus: (1) Was there a significant change in the length and weight of the rainbow trout in Paul Lake, British Columbia, during the period from 1932 to 1935 while the stock in the lake was increasing? (2) Was there a significant change in the length-weight relationship during the same period?

The answer to the first problem has already been suggested by interpreting the decrease in average weight from 1.5 pounds to 1.0 pounds as a significant change. It remains to test this for significance and to investigate the changes in the length of the fish in different years. The investigation of the second problem will throw some light on the condition of the fish.

The only solution that can be stated exactly is the hypothesis that there has been no change in either length, weight or the length-weight relationship. Briefly stated it would read thus: Although differences in length and weight and in the length-weight relationship will be found from year to year, these differences are actually no greater than is to be expected on the basis of the normal variation of this kind of biological material. If this hypothesis is refuted by the evidence, then it may be assumed that changes have taken place which in turn might be related to the change in the stock of fish in the lake.

Material and Methods

In the course of the Paul Lake investigations the writer collected data each year from several hundred fish. For the present problem it becomes a matter of selecting sufficient material to conduct the test.

It seemed advisable to draw representative, homogeneous samples from the collections rather than to use data from the population as a whole. Accordingly two sets were selected. The first consists of five series of 10 immature, yearling, female trout caught by angling during the last two weeks of September in each of the years from 1931 to 1935, inclusive. The second set consists of four series of 20 immature, 2-year old, female rainbow trout caught by angling during the first 2 weeks of May in each of the 4 years from 1932 to 1935, inclusive. Both sets were selected at random by means of a statistical procedure.

The length of each fish was measured from the tip of the snout to the mid-fork of the tail and was recorded to the nearest millimeter. The weight was measured and recorded to the nearest tenth of a pound. The weight data were converted to decagrams to facilitate transformation to logarithms. The state of maturity was judged by an examination of the ovaries. Normally, the majority of the female rainbow trout at Paul Lake spawned at 3 or 4 years of age, so none of the fish was fully mature. Incidentally the condition of immature fish is more difficult to judge; the writer (Mottley, 1938) has shown that mature female trout lose approximately 25 per cent of their weight at spawning time and the change in condition is quite apparent. The age of each fish was determined from a sample of its scales by means of criteria reported in a manuscript which is filed at the Pacific Biological Station, Nanaimo, British Columbia and at the Royal Ontario Museum of Zoology, Toronto, Ontario. The yearlings were 1-year old fish on the previous May; the 2-year olds were just entering their third year of life.

The design of the test of the significance of differences of length and weight between the different series of fish is the standard design for the analysis of variance. The length-weight relationship may be investigated by the standard design for the analysis of covariance. In order to avoid curvilinear regression between length and weight the original data should be transformed to common logarithms. The pattern of the test is given by Snedecor (1940), and reference should be made to this text for all symbols and procedures used here.

The Data

The original data are shown in Tables 1 and 2. The reduced data based on the logarithms of the original lengths and weights which are necessary for the tests of significance are shown in Tables 3, 4 and 5. The best estimate of the error of the mean length in any given year may be obtained from the value, Sx^2, for within-years; likewise the best estimate of the error of the mean weight in any given year may be obtained from the value, Sy^2, for within-years. The calculation of the errors of estimate necessary for the analysis of covariance are also shown in Tables 3 and 4.

Table 1.—Lengths in centimeters and weights in decagrams of five series of yearling, immature, female rainbow trout caught by angling at Paul Lake, British Columbia, during the last 2 weeks of September from 1931 to 1935

1931		1932		1933		1934		1935	
Length	Weight	Length	Weight	Length	Weight	Length	Weight	Length	Weight
34	50	33	54	30	32	30	32	30	27
33	50	33	45	28	27	29	32	29	27
32	45	30	32	27	23	28	27	28	23
32	45	29	32	25	18	28	23	28	23
31	41	28	27	24	23	27	23	26	18
31	36	28	27	24	18	26	27	25	18
31	36	27	27	24	14	26	18	25	14
29	27	27	27	23	14	25	18	24	18
27	27	24	18	22	14	24	23	24	14
26	18	24	18	22	14	21	10	21	14
Mean 30.6	37.5	28.3	30.7	24.9	19.7	26.4	23.3	26.0	19.6

Table 2.—Lengths in centimeters and weights in decagrams of four series of 2-year old, immature, female rainbow trout caught by angling at Paul Lake, British Columbia, during the first 2 weeks of May from 1932 to 1935

1932		1933		1934		1935	
Length	Weight	Length	Weight	Length	Weight	Length	Weight
43	130	42	82	39	73	35	54
42	120	41	73	38	73	35	50
41	95	41	73	38	77	35	50
40	100	40	73	38	77	35	45
40	95	39	73	37	63	35	54
40	95	39	54	36	54	34	50
40	95	39	68	35	54	34	41
40	86	38	68	34	45	34	45
39	86	38	50	34	54	34	41
39	77	38	64	34	50	33	36
38	82	37	54	34	45	33	41
38	77	36	41	33	50	33	36
38	73	36	54	33	45	33	41
37	86	36	45	33	45	32	41
36	59	36	45	32	45	32	41
36	45	36	45	32	45	32	36
35	54	35	36	31	41	32	41
33	50	34	36	30	32	31	41
33	45	32	27	28	23	31	36
31	36	31	23	26	18	31	36
Mean 38.0	79.3	37.2	54.2	33.8	50.4	33.2	42.8

Table 3.—The reduction of the logarithms of the data in Table 1 for the analysis of covariance and the test of significance

Source of variation	Degrees of freedom	Sums of squares and products		
		Sx^2	Sxy	Sy^2
Total (5 years)	49	0.1446	0.4278	1.4358
Between years	4	0.0500	0.1679	0.5877
Within years	45	0.0946	0.2599	0.8481

Errors of Estimate

Source of variation	Degrees of freedom	Sums of squares	Mean square
Total	48	0.1702	
Within years	44	0.1341	0.003048
For test of significance	4	0.0361	[1]0.00902

$$[1]F = \frac{0.00902}{0.003048} = 2.96;\ n_1 = 4;\ n_2 = 44.$$

Table 4.—The reduction of the logarithms of the data in Table 2 for the analysis of covariance and the test of significance

Source of variation	Degrees of freedom	Sums of squares and products		
		Sx^2	Sxy	Sy^2
Total (4 years)	79	0.1413	0.4956	2.1209
Between years	3	0.0504	0.1553	0.6965
Within years	76	0.0909	0.3403	1.4244

Errors of Estimate

Source of variation	Degrees of freedom	Sums of squares	Mean square
Total	78	0.3826	
Within years	75	0.1504	0.0020
For test of significance	3	0.2322	[1]0.0774

$$[1]F = \frac{0.0774}{0.0020} = 38.7;\ n_1 = 3;\ n_2 = 75.$$

Table 5.—The deviation from expectation of the mean weights of yearling and the 2-year old rainbow trout in different years

[The regressions are based on the logarithms. The means adjusted for the differences in length are shown in Column 6]

Year	Mean length (X)	Mean weight (Y)	Expected mean weight (E)	$Y - E$	Adjusted mean weight
Yearlings ($E = 2.747\ x - 2.549$)					
1931	1.484	1.555	1.528	+0.027	1.412
1932	1.450	1.464	1.434	+0.030	1.415
1933	1.394	1.278	1.280	—0.002	1.382
1934	1.419	1.348	1.349	—0.001	1.384
1935	1.413	1.281	1.332	—0.051*	1.333
2-Year-Olds ($E = 3.754\ x - 4.072$)					
1932	1.577	1.876	1.831	+0.045*	1.767
1933	1.570	1.709	1.805	—0.096*	1.627
1934	1.526	1.676	1.640	+0.036*	1.758
1935	1.520	1.627	1.617	+0.010	1.732

*Significant.

The Tests of Significance

Change in size.—Significant differences between the mean values in the data can be detected by the application of the F-test. The variance of the length of yearlings between years is $\frac{0.0500}{4} = 0.0125$, whereas the variance of length within years is $\frac{0.0946}{45} = 0.0021$. Therefore, $F = \frac{0.0125}{0.0021} = 5.95$, which is a highly significant value for $n_1 = 5$, $n_2 = 45$, degrees of freedom. The decrease in length beyond 1932 is apparent from the mean values in Table 5.

A similar treatment of the data for the 2-year olds provides an F-value of 14.0, which is highly significant.

The changes in weight are likewise significant. The F-value for the yearlings is 7.79; the F-value for the 2-year olds is 12.4. The reduc-

tion in weight in the two series is so apparent from the data that the tests scarcely need to be applied.

Change in length-weight relationship.—The changes in the length-weight relationship, however, are not so evident and the statistical tests are necessary. The *F*-values are supplied in Tables 3 and 4. There is a significant difference between the adjusted mean weights for the yearlings and there is a highly significant difference in the adjusted mean weights of the 2-year olds. The adjusted mean weights are shown in the right-hand column of Table 5. These are the weights to be expected if the lengths of the fish were all reduced to a standard which, in the case of the yearlings is 1.432, the mean for the 50 fish; in the case of the 2-year olds it is 1.548, the mean for the 80 fish. It is apparent that the yearlings in 1935 weighed less than expected on the basis of their length; likewise the 2-year olds in 1933 were much below expectation.

In order to evaluate the significance of the different mean weights the standard error of estimate was calculated. A difference in the yearlings in the fifth column of Table 5 greater than 0.0175 or of 0.0100 in the 2-year olds is considered to be significant. The yearlings showed a downward trend from 1931 and 1932 until significance is reached in 1935. The 2-year olds were significantly above expectation in 1932 and dropped significantly below it abruptly in May 1933, but were above expectation in 1934 and 1935. Apparently the 2-year olds lost weight during the winter of 1932-33 because they were in good condition as yearlings in September 1932. It would be interesting to follow the trends of the several year-groups and to investigate the factors involved in the fluctuations but further investigation lies beyond the scope of the present problem and the data in hand.

Conclusions

Significant reductions in both the length and weight of the immature yearling and 2-year old female rainbow trout occurred at Paul Lake from 1932 to 1935. These changes are apparently related to the increase in the stock of trout in the lake during the same period. Significant fluctuations were also found in the length-weight relationship but the changes were not directly related to the increase in the stock in the lake. It is possible that the variations in relative heaviness may be associated with a differential survival of the different broods but this is a question for further inquiry.

There is some indication from the data that a stocking policy which calls for a planting of a high proportion of trout in relation to the number produced naturally in a depleted body of water should be adjusted on a graded scale. This recommendation applies, especially, where the number surviving is controlled by cannibalism. For instance, if the policy, as at Paul Lake, calls for 200 fry per acre, the number should be built up gradually; e.g., 100 per acre may be planted

the first year, 150 the second year and then 200 per acre the third year. This procedure should overcome the danger of a high survival from the initial planting with its subsequent effect on the food supply and the size and condition of the fish. The relation between survival, the food supply and the size and condition of the fish will be reported later in a separate paper.

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REARING MASKINONGE IN A PROTECTED AREA

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ABSTRACT

A method of rearing maskinonge to an advanced fingerling stage was investigated. One hundred thousand fry were planted in a natural habitat; a marshy bay normally used by maskinonge as a spawning ground. An attempt was made throughout the summer to remove all possible fish and turtle predators. Altogether 17,334 coarse fish, exclusive of fry of the year, and 563 turtles were removed from the area. Less than one-third of the fish and somewhat more than one-half of the turtles were removed previous to planting the maskinonge fry.

Maskinonge spawn in the spring and the fry remain in the spawning marshes at least until the first of November. The fry show little tendency to range about during the period.

When first commencing to feed maskinonge fry took plankton crustacea and the cladoceran, *Polyphemus pediculus*, was utilized to a large extent. About 1 week later they commenced to take very small minnow fry as well as plankton. After they were about 5 weeks old the diet was composed entirely of fish. Cannibalism did not occur when there was an abundant supply of other food.

Maskinonge grew very rapidly under the conditions provided, reaching an average length of nearly 10 inches by the first of November.

A yield of 0.8 advanced fingerlings for each 1,000 fry planted was obtained. However, since the removal of fingerlings was not completed the yield was probably greater. Many predatory fish, notably yellow perch and rock bass, remained in the area throughout a greater portion of the experimental period. There can be little doubt that their predatory activities reduced the yield.

Advantages of raising maskinonge fingerlings under the conditions described are the abundant natural food supply, making possible excellent growth, and the possibility of eliminating predators to a large extent.

INTRODUCTION

Although the maskinonge, *Esox m. masquinongy* Mitchill, is in more danger of depletion than the majority of our game fishes, it probably has received less attention from fish-culturists than most other species, principally because of the difficulties involved in artificial propagation of maskinonge. One difficulty is to provide, under usual hatchery conditions, a sufficient supply of the right kinds of food. Otherwise the young fish develop cannibalistic tendencies and the stock is rapidly depleted. To circumvent this difficulty the fry are usually planted when about 3 weeks old, which is approximately the time they commence to feed. It seems to be accepted by fish-culturists, however, that it is generally a more satisfactory procedure to plant the young of game fishes at a somewhat more advanced stage. Certainly young maskinonge of the size usually planted are particularly vulnerable to the attacks of fish and other predators which abound in the usual

habitats of maskinonge fry. Attempts to raise maskinonge to a more advanced stage in hatcheries have met with varying degrees of success.

In 1939 one of the experiments undertaken by the Ontario Game and Fisheries Department was an attempt to raise maskinonge to an advanced fingerling stage under conditions approximating as closely as possible an "ideal" natural environment. An area normally used by adult maskinonge for spawning was chosen for the experiment. It was closed off from adjoining waters and an attempt made to rid the area of predators and competitors of the young maskinonge. Maskinonge fry from a hatchery were planted in the area and their development in subsequent months was observed.

Description of the Area

The Burleigh Falls maskinonge rearing station is a marshy bay in Stony Lake, one of the chain of Kawartha Lakes. The bay comprises about 10 acres and is fronted by a large island, so that by constructing barriers at two places, one 50 feet, the other 150 feet long, the bay could be completely closed off from the remainder of the lake. The barriers were made of 2-inch sheet piling supported by stringers. Ports, closed with bronze screening, were left in the barriers to allow circulation of water through the area. The depth of water was fairly uniform throughout the area, averaging 3 to 5 feet. During the summer the water level did not vary by more than a foot, this being the result of the control of water height in the Trent Canal system. The minor fluctuations served to insure some circulation of water through the area. The highest water temperature recorded was 89° F. on July 27. The bottom consists of a layer of soft muck which is 2 to 6 feet deep over most of the area.

Vegetation is very abundant throughout the area, particularly in mid-summer. In the early spring islands of floating bog-supporting sedges, cattails and shrubs such as *Ledum* were the only vegetation. Early in the summer water lilies, pickerel weed and potamogetons appeared in abundance. In midsummer wild rice, bladderwort and water milfoil were very common. In the late autumn after the emergent vegetation had died potamogetons were the dominant flora.

The marsh supported an abundant fauna of typical forms. A complete evaluations of the various forms was not attempted. A list of some of the commoner species will serve to illustrate the population of the area. Common suckers (*Catostomus c. commersonnii*), bullheads (*Ameiurus n. nebulosus*), yellow perch (*Perca flavescens*), common sunfish (*Lepomis gibbosus*), and rock bass (*Ambloplites rupestris*) were the principal coarse fish. Game fish included maskinonge (*Esox m. masquinongy*), smallmouth black bass (*Micropterus dolomieu*), and largemouth black bass (*Huro salmoides*). The most abundant minnows were the golden shiner (*Notemigonus crysoleucas auratus*), the blunt-nosed minnow (*Hyborhynchus notatus*), the black-chinned

shiner (*Notropis heterodon*), and the northern black-nosed shiner (*Notropis h. heterolepis*). Minnows of less frequent occurrence were the mud minnow (*Umbra limi*), and the Iowa darter (*Poecilichthys exilis*). Both tadpoles and adults of the leopard frog and the bullfrog were abundant. Four species of turtles occurred in the marsh: The musk turtle (*Sternotherus odoratus*); Blanding's turtle (*Emys blandingi*); painted turtle (*Chrysemys marginata*); and the snapping turtle (*Chelydra serpentina*). Water snakes (*Natrix sipedon*) were common. Birds and mammals appeared to be relatively unimportant.

Both phytoplankton and zooplankton were well represented in species and individuals. Swarms of cladocerans, principally *Bosmina* sp. and *Polyphemus pediculus* occurred about the margins of sedges and cattails in the early summer and were particularly important as a constituent of the diet of very young maskinonge fry.

Three species of predaceous aquatic insects were common. These were diving beetles, *Dytiscus* sp.; giant water bugs, *Benacus griseus;* and water scorpions, *Ranatra* sp. On several occasions individuals of *Ranatra* sp. were observed feeding on small black bass fry and the possibility that maskinonge of a similar size might fall prey to these insects must be considered.

Experiment

At the time the area for rearing maskinonge was selected, on May 12, adult maskinonge were seen spawning there. This meant that a determination of the yield on the basis of fry planted would not be possible. To obviate this difficulty a small area, about one-tenth of an acre in extent, was closed off from the rest of the marsh. This plot was not particularly suited to spawning and it was free of spawning maskinonge. Fry were planted in this sub-area in the same density as in the rest of the experimental bay.

Removal of unwanted fish, by means of gill nets and hoop nets, was commenced as soon as the experimental area was closed off from the body of the lake. Later in the season small traps set for maskinonge fingerlings took many coarse fish. All gill nets were removed as soon as the maskinonge fingerlings were large enough to become enmeshed. Game fish were transported to outside waters and coarse fish were killed.

On June 4, 1939, 100,000 maskinonge fry which were about 3 weeks old were planted in the area. The fry were scattered around the edges of the bay and the small marshy islands, wherever there was an abundance of zooplankton which appeared to be suitable as food for the fry. As an experimental control 1,000 fry were planted in the sub-area believed to be free from naturally deposited spawn.

At various times during the summer fry were kept in small cages made of wood and screening in order to observe their habits of feeding and movement. At times it was possible to observe young mas-

kinonge in the main area, although as a rule they were difficult to see when not confined in a very small space. In addition to observing the feeding activities of the fish some information as to their food was gained by analysis of the stomach contents of a few specimens which were preserved.

The rate of growth was determined by measuring the length of all individuals removed from the area before they were liberated. As a check on the growth rate, scales of the preserved specimens were examined under the microscope. While the collection of preserved specimens was small it covered the size range rather completely.

Predators Removed

The numbers of fish and turtles removed from the area are given in Table 1. The figures are of particular importance as giving an indication of the population of the 10-acre marsh. It should be borne in mind that these figures indicate the population at the time the marsh was closed off from adjacent waters in the spring. Black basses and maskinonge, and to some extent possibly rock bass and sunfish, were at that time moving into the marsh to spawn. Probably the adult maskinonge are the only fish which move out of such areas during the summer. No record was kept of the fry of the year of species of coarse fish removed. However, 691 black bass fingerlings (mostly largemouth) from 2½ to 4 inches long and 81 maskinonge fingerlings ranging from 4 to 11½ inches in length were removed from the area and planted in suitable places in the main lake.

The large population of minnows was left in the area as a source of food supply for the maskinonge. Golden shiners, blunt-nosed minnows, black-nosed shiners and black-chinned shiners spawned abundantly in the area.

Table 1.—Numbers of fish of various species removed from maskinonge rearing area at Burleigh Falls

Species	Month						Before planting fry	After planting fry	Total
	May	June	July	August	September	October			
FISHES:									
Bullheads	324	194	66	41	9	4	380	258	638
Common sunfish	3,606	4,695	1,335	923	868	289	4,762	6,954	11,716
Rock bass	405	398	167	41	41	25	467	610	1,077
Largemouth black bass	229	264	4	....	....	....	320	177	497
Smallmouth black bass	17	....	....	....	....	....	17	....	17
Yellow perch	25	119	116	674	918	1,434	30	3,256	3,286
Common suckers	13	49	15	....	....	2	23	56	79
Maskinonge	19	5	....	....	....	....	20	4	24
Total fishes	4,638	5,724	1,703	1,679	1,836	1,754	6,019	11,315	17,334
TURTLES:									
Musk	171	112	54	24	5	....	191	175	366
Blanding's	3	16	9	....	....	....	6	22	28
Painted	27	63	15	17	....	....	47	75	122
Snapping	7	30	7	2	1	....	14	33	47
Total turtles	208	221	85	43	6	....	258	305	563

Distribution and Movement of Young Maskinonge

As already indicated, the maskinonge fry were planted along the margins of emergent vegetation such as sedges and cattails. During the next 10 days fry could be seen in these locations either close to the edge of the vegetation or right in among the submerged stems of the plants. They did not spread out very rapidly at this time and frequently several fry would be seen within a distance of a few feet.

By June 15, maskinonge became increasingly difficult to find about the edges of the marsh. This was coincident with the appearance of minnow fry, on which the young maskinonge were feeding. At times small maskinonge were encountered in open water some distance away from the weed beds. During July no young maskinonge were seen, and by August they had spread throughout the entire area when they were found most frequently about the beds of pondweed which had grown up in what was open water when the fry were planted. Few individuals were actually seen in the dense weed beds but their presence was demonstrated by their occurrence in traps set in such localities. Maskinonge fingerlings continued to be found in this type of habitat until the formation of ice over the entire area on the first of November. Observations were concluded at this time. One reason for the difficulty in observing the fingerlings in nature is the facility with which they conceal themselves in even a small amount of vegetation, or in the bottom muck. Captive specimens were extremely adept at hiding under very small bits of debris. As a rule they lie quite still, but when startled they move with such rapidity that it is difficult to follow their movement.

The young maskinonge do not range very widely in search of food, but rather lie in wait while the food organisms range about. Thus for the first 10 days after planting, fry could be found at identical spots day after day. Again, in trapping the fingerlings, one setting of a net would frequently take two or more individuals, but usually several days intervened between the catches, suggesting that those fish in the immediate vicinity moved about rather slowly. A leader 40 or 50 feet long was no more effective on the traps than a leader half that length, once again suggesting a limited tendency to range about. Finally, the fact that young maskinonge were nearly always found in certain well-defined areas, namely submerged weed beds, indicates a lack of wandering.

Feeding Habits

The tendency of the fry, when first planted, to lie in the midst of swarms of plankton Cladocera has already been mentioned. Much of the time the fish would remain quietly suspended in the water and occasionally they would dart at one of the larger plankton organisms and capture it. Analysis of stomach contents showed that the fry were feeding principally on *Polyphemus pediculus,* although two spe-

cies of *Bosmina* were far more numerous in the plankton. *Polyphemus* is, of course, much the larger of the two species.

When 4 to 5 weeks old the maskinonge commenced to feed on very small minnow fry and for about a week at this time the diet was a mixed one consisting of both cladocerans and fish. Soon fish became more important in the diet and by the time the fry were 5 weeks old small fish constituted practically the sole item in the food.

When the young maskinonge first began to feed on the minnow fry they were very inefficient at catching their prey. Very often the strike resulted in a complete miss. Frequently even when the fish was captured it escaped while being brought into position for swallowing. In the observed instances the minnows which escaped were invariably injured so seriously that they died in a short time. At no time was a maskinonge observed to strike at a crippled minnow, but without exception they attacked only healthy minnows. For the first week, while learning to catch minnows, the maskinonge in cages killed approximately six minnow fry for every one actually eaten. This meant that a considerable surplus over the actual food requirements had to be provided. When 7 weeks old the maskinonge in captivity were quite proficient at retaining captured minnows, and to miss a strike was much less common than formerly, though still by no means a rare occurrence.

Cannibalism has been reported as one of the chief obstacles encountered in raising maskinonge fingerlings in hatcheries. An experiment to test the danger of cannibalism when there was a good supply of food was performed in the following manner. Five maskinonge fry were placed in a cage 10 by 20 inches and 2 inches deep. On June 15 three of the fish were 1 inch long and two were 1½ inches. By July 15 the three small fish were 2 inches long and the larger fish 3 and 3½ inches, respectively. There was no indication of cannibalism during the month of the experiment; but at the commencement of the experiment the cage was placed where swarms of cladocerans could move in and out of it and later it was kept well stocked with minnow fry. Hence the danger of cannibalism seems to be relatively small if there is a good supply of suitable food.

The relationship between maskinonge fry and the fry of two other species occurring abundantly in the area was investigated by placing maskinonge fry and largemouth black bass fry in one instance, bullhead fry in the other, in the same containers. Up to the end of July neither maskinonge nor bass showed any inclination to molest each other, but competition for food between the two species was very keen. The young largemouth bass proved much more adept than the maskinonge at snapping up minnow fry. This does not mean, of course, that as soon as there is sufficient discrepancy in size the two species might not prey on each other. Bullheads were not eaten by the maskinonge, neither was any direct competition for food observed.

In addition to observing the feeding of live fish an analysis of the

stomach contents of 22 young maskinonge was made. These fish ranged from five-eighths of an inch to 17½ inches in length (Table 2). The larger fingerlings fed on a variety of fish, presumably whatever happened to be most available to them.

Table 2.—Stomach contents of young maskinonge

Date of capture	Number of stomachs	Size-range of fish (inches)	Approximate age of fish (weeks)	Contents (Number and size of food organisms in parentheses)
June 6	3	0.6	3	*Polyphemus pediculus* (33); cladoceran, unidentified (1); minnow fry (2 — 0.25 in.).
" 14	1	1.0	4	Minnow fry (1 — 0.5 in.).
" 21	1	1.2	5	Minnow fry (1 — 0.5 in.).
" 30	2	1.6, 2.3	6	Minnow fry (2 — 0.4-0.5 in.).
July 1	1	1.6	6	Empty.
" 6	1	3.5	7	Minnow fry (1 — 0.4 in.).
Aug. 5	2	5.5, 6.5	10	*Notropis heterodon* (1 — 2.5 in.); *Umbra limi* (1 — 2.8 in.).
Sept. 1	2	5.9, 7.8	14	*Notemigonus crysoleucas auratus* (1 — 3.3 in.).
Nov. 1	5	8.5-11.5	22	*Perca flavescens* (1 — 2.5 in.); *Lepomis gibbosus* (1 — 1.5 in.); *Umbra limi* (1 — 3.5 in.); fish remains, unidentified.
June 4-22	3	12.5-13.6	52	*Notemigonus crysoleucas auratus* (1 — 3.5 in.); fish remains, unidentified.
June	1	17.5	104	Empty.

Rate of Growth

The rate of growth of maskinonge during the first year is extremely rapid. All specimens recovered from the area were measured before being liberated and the resulting data are plotted in Figure 1. In the first 6 months maskinonge reached a length of 8 to 11½ inches, with an average length of about 10 inches. The approximate range in length of the maskinonge on the dates indicated was as follows: June 6, ⅝ inch; July 5, 2¼ to 3½ inches; August 1, 4 to 6¾ inches; September 1, 4 to 8½ inches; October 1, 4½ to 9½ inches; November 1, 8 to 11½ inches.

As a further check on the rate of growth, the scales from a small series of specimens were examined under a microscope. The smallest specimens to show a distinct annual ring were 12½ and 13½ inches long and were taken in June while clearing the area of unwanted fish. Table 3 summarizes the information obtained from examination of the scales.

Recovery of Maskinonge Fingerlings

During the season 81 maskinonge fingerlings were removed from the area. All but a few which were kept as specimens were transferred to other marshy bays opening into the lake. The number includes also four dead specimens picked up in the area. This recovery

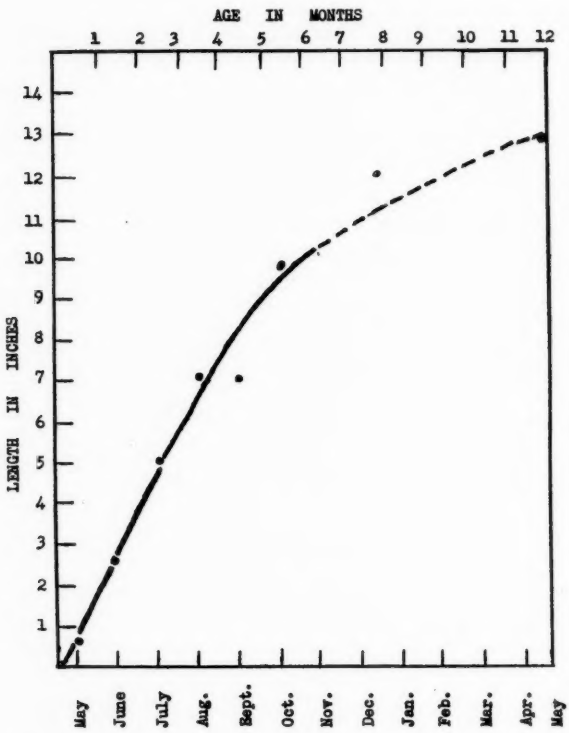
AGE IN MONTHS
1 2 3 4 5 6 7 8 9 10 11 12
LENGTH IN INCHES
14 13 12 11 10 9 8 7 6 5 4 3 2 1
May June July Aug. Sept. Oct. Nov. Dec. Jan. Feb. Mar. Apr. May

Figure 1.—Rate of growth of young maskinonge from May to November and projected growth (dotted line) from November to May as indicated by data obtained from 97 specimens collected during the period June to November, 1939.

Table 3.—Information obtained from examination of scales of young maskinonge

Length of fish (inches)	Date of capture	Number of annuli on scales	Number of circuli outside of last annulus
2.9	July 3	0	8
6.5	Aug. 5	0	29
7.8	Sept. 1	0	34
8.5	Nov. 1	0	43
9.9	" "	0	59
10.3	" "	0	60
10.5	" "	0	63
12.6	June	1	15
13.1	"	1	16
13.6	"	1	18
17.5	"	2	15

is at the rate of 0.8 advanced fingerling per 1,000 fry planted. The recovery from the sub-area was 7 fingerlings from 1,000 fry. In both instances factors entered into the situation which make these figures open to question. In the main area there was every reason to believe that a considerable number of large fingerlings were left in the marsh at the conclusion of the experiment, particularly since in the last 4 days 17 fish, 8½ to 11½ inches long, were taken with but one setting of nets. It is not known how much spawn was deposited in the area before it was closed off in the spring and even in the sub-area there was no certainty that all fingerlings were recovered. Moreover in this area the food supply was not as good as in the main area. Some coarse fish remained in this area, also, at the time the maskinonge fry were planted.

It is safe to say that while the results obtained the first year of the experiment were promising much better results might be expected from this method of cultivating maskinonge. A considerable number of predaceous fish, notably yellow perch and rock bass, remained in the area during much of the period. A satisfactory method for recovery of the fingerlings has yet to be developed. A study of the movements of the fish from late fall to early spring might yield valuable information, for while there was no pronounced movement of maskinonge fingerlings from the area by November, only three yearling maskinonge were taken in the area in the spring. This indicates that sometime during their first year the maskinonge move out of the spawning marshes. It might be feasible to take advantage of that movement in gathering the fish for liberation. Certainly, the excellent growth of the young maskinonge warrants further investigation of the possibilities of this method of propagation.

A METHOD OF INCREASING THE CAPACITY OF A TROUT HATCHERY

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ABSTRACT

A new method of increasing the capacity of a trout hatchery has been developed through the use of small circular tanks. These tanks are superimposed and fastened independently by means of a swivel arrangement, to a vertical post. The use of this method for incubating trout eggs and rearing fry has increased by four times the potential capacity of a hatchery at Saint Faustin, Quebec, where the new method was developed.

The hatching and rearing capacity of a hatchery ordinarily is limited by the water supply and by the area of floor space in the building. The equipment of trout hatcheries usually consists of long, narrow, shallow troughs arranged in tandem. Such an arrangement permits the utilization of only about one-fortieth of the cubic capacity of a building for hatching or rearing purposes. A new type of equipment has been perfected which will increase the capacity of the hatchery four times.

The new equipment, developed at Saint Faustin, Québec, is illustrated in Figure 1. Small circular tanks are superimposed and suspended at one edge from a vertical pipe or column and are arranged on swivel fastenings so that each tank may be moved independently of the others. The vertical support is fastened both to the floor and to the ceiling so that the superposition of five tanks, with a 6-inch space between the top edge of one tank and the bottom of the tank immediately above, will make the total height of the working unit about 8 feet. A horizontal support constructed of pipe and fastened to the vertical column provides rigid support for each tank. The height of the water in the tank may be regulated as described below. The customary arrangement is to have the water enter the top tank and pass through each tank in the vertical series in order. An alternative arrangement is provided, however, whereby fresh water can be supplied directly to each tank. Although the general installation illustrated in Figures 1 and 2 has been in use during the 1938 and 1939 seasons for handling eggs, fry and fingerlings, further experiments are in progress. Particulars of the new developments will be withheld until they have been tested thoroughly. The discussion in this paper, therefore, will be limited to the equipment in actual operation.

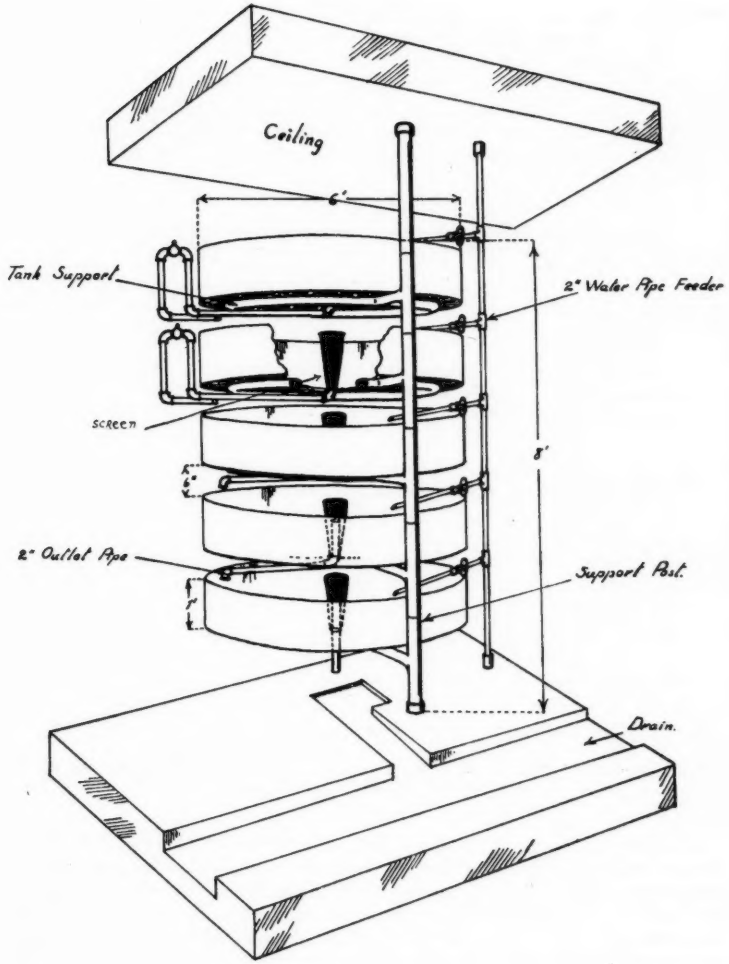

Figure 1.—Diagram of the vertical assembly of five superimposed tanks for the hatching and rearing of trout. Each tank rests independently on a support constructed of pipe (bottom of Figure 2) which is attached to the vertical supporting column so that tanks may be moved horizontally to facilitate caring for the eggs and young fish.

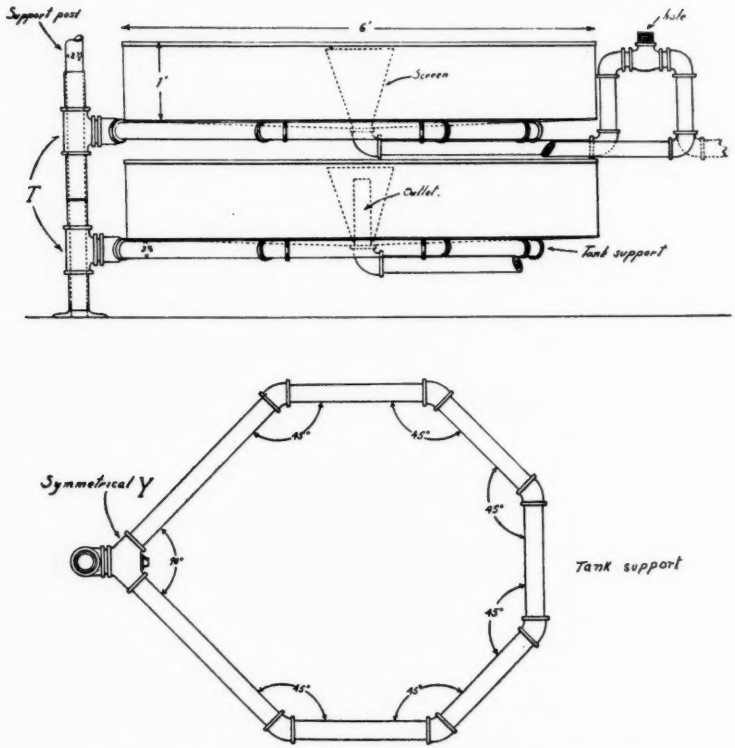

Figure 2.—Details of the supporting cradle and swivel attachment for superimposed circular hatchery tanks.

The method of regulating the level of water in the tanks is illustrated in Figure 2. One method (below) consists of a pipe placed inside the screen in the center of the tank which is connected beneath the tank to a horizontal pipe that leads to the inside edge of the tank immediately below. In the other, (upper tank illustrated) no pipe has been placed inside the screen but the water level is regulated by vertical and horizontal side pipes, arranged in the form of an inverted "U." Any desired level of water may be obtained by inclining the "U." The water is conducted to the tank below through the "U" which leads into a short pipe that carries the water to the inner edge of the tank. Note that a small hole is placed in the plug inserted in a

"T" in the horizontal part of the inverted "U." If that hole were not present all of the water would be siphoned from the tank.

The lower portion of Figure 2 illustrates the manner in which the cradle or swivel supports for the individual tanks are constructed.

Principal dimensions for the construction of either 4-foot or 6-foot tanks are listed in Table 1. For experimental purposes the 4-foot tank is recommended.

Table 1.—Dimensions for the construction of 4-foot and 6-foot circular hatchery tanks

Item	Diameter of tank[1]	
	4 feet	6 feet
Diameter of vertical support	2½ inches	3 inches
Diameter of "T's," "Y's," and short pipes around vertical support	3 inches	3½ inches
Diameter of tank support	2 inches	2½ inches
Approximate circumference of tank support	11 feet	16 feet
Slope of tank bottom	⅛ inch per foot	⅛ inch per foot
Gauge of galvanized sheet iron	20	10
Approximate weight of tank with water to 9-inch mark	600 pounds	1,400 pounds
Approximate capacity of trout fingerlings per tank	1,000	2,000

[1]Dimensions of pipe and pipe fittings are inside diameters.

The rather slender diameter indicated for the vertical supporting columns may surprise many fish-culturists. However, it has been determined that a 2-inch pipe of the length required here will support a maximum weight of 2,000 pounds. The pipe for the supporting post should be chosen with care to insure that it is straight and has a smooth surface. Powdered graphite should be used inside the "T's" of the tank support to insure freedom of movement. To make the system rigid and keep it in proper alignment it is recommended that the various nipples and elbows used to construct the supports for the individual tanks be welded together.

To employ the system on a large scale, a general arrangement similar to that indicated in Figure 3 is recommended. A floor space 40 by 80 feet is required, in which eight groups of tanks, each group consisting of four series of five vertically arranged tanks may be accommodated. Thus, 160 tanks may be placed on one floor and will have a trout fingerling capacity of about 320,000. With a two-story building such as has been planned at Saint Faustin, Québec, 320 tanks can be accommodated which will have a total capacity of about 640,000 fingerlings.

Water is brought to the tanks by a 6-inch pipe lying in a trench in the floor. From this supply pipe, a 4-inch pipe rises vertically to carry water to each group of tanks, and from it branches lead to each tier or to each individual tank. (As indicated in Figure 1, fresh water may be furnished to each tank, or the water may flow downward from the top through each of the tanks in the vertical series, whichever is desired.)

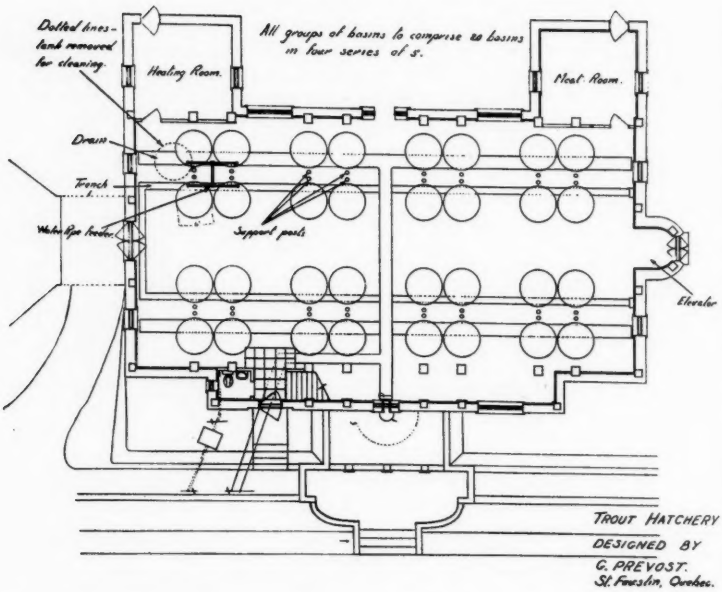

Figure 3.—Floor plan of a trout hatchery equipped with batteries of superimposed circular tanks.

When in position the tanks have little space between them, but because of the swivel arrangement each tank may be swung away from the others in the same vertical series. A tank moved out from the series may be cleaned readily, or the fish can be fed and any other necessary operations conducted with comparative ease. To drain an individual tank it is necessary only to remove the standpipe inside the center screen. If the side-pipe arrangement is used, the inverted "U" is shifted to a downward position and the water will pass out of the hole in the plug and fall into the drain (Figure 2).

The advantages of round pools over rectangular troughs have been described many times by different authors. Round pools are easy to clean, accommodate more fish for the same volume of water, are conducive to better and more uniform growth of the fish, provide good circulation of the water, and the fish are distributed more evenly throughout the tank. Uniform distribution is very important in caring for fry in tanks since they tend to crowd badly into the corners of rectangular troughs.

In addition to these well known advantages, the circular tank system described here provides for optimum use of available space. The floor space necessary for the operation of 5 tanks is 50 square feet. Troughs to accommodate a comparable number of fish, on one plan, would require 200 square feet. Because of the superimposed tanks the same water may pass through five tanks (under the two-floor plan at Saint Faustin, through 10 tanks). There is no objection to the use of the same water for 10 tanks of eggs and vesiculated fry, and according to the Taylor system, the same water may be used as many as 18 times during the feeding periods of fry and fingerlings without any adverse effects. If at any time the repeated use of the same water becomes a source of trouble, fresh water may be supplied to each individual tank by changing the drains so that they flow outside of the tanks and opening the individual feeder values (Figure 1).

To compete with the capacity of the system proposed here an ordinary trough hatchery would require a floor space of 40 by 300 feet, instead of the 40 by 80 feet employed here. The advantages of the circular tank system are very material, therefore, from an administrative point of view.

Discussion

Mr. A. V. Tunison: How many 2-inch fish will the circular tanks carry?

Mr. Prevost: Last spring we carried 25,000 fry in the 6-foot tanks. I believe that we can carry 1,000 fingerlings, 3 to 4 inches long, in the 6-foot tank, which is approximately the same number that would be carried in an ordinary hatchery trough.

Mr. J. R. Brett: What is the cost of these tanks?

Mr. Prevost: A complete set of five tanks would cost from $100 to $150, provided the work was done by men employed in the hatchery.

SEASONAL VARIATIONS IN STOMACH CONTENTS AND RATE OF GROWTH IN A POPULATION OF YELLOW PERCH

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Abstract

The yellow perch, *Perca flavescens* (Mitchill), of Costello Lake, Algonquin Park, Ontario, were sampled regularly from June to September, 1937, by means of minnow traps. From this 89-acre lake about 750 individuals were taken for an analysis of growth and feeding habits.

The period of maximum growth changed progressively from July in age-group I to August for fish in age-group III. Seasonal variations in the volumes of stomach contents were directly correlated with seasonal changes in the growth increments. This correlation was so well marked that food is believed to be the primary factor controlling growth in this perch population.

Introduction

The productivity of lakes with respect to any particular species of fish can be fully understood only through an analysis of the many environmental factors affecting that species in a number of lakes. The present report on the relationship between seasonal growth and feeding habits in a perch population is preliminary to a more extensive analysis of growth, distribution, and utilization of food by the yellow perch, *Perca flavescens* (Mitchill), in a series of Algonquin Park lakes.

Costello Lake, with an area of 89 acres, a maximum depth of 60 feet and a thermocline at 15 to 18 feet in midsummer, was fished regularly during the summer of 1937. Samples of the yellow perch population were obtained by setting minnow traps in a series of depths and removing the fish at frequent intervals during the day. Bread, used as bait, was enclosed in wire boxes to prevent contamination of stomach contents. Age-groups I, II, and III were obtained in sufficient numbers (about 750), from mid-June to mid-September, to make possible an analysis of feeding and the plotting of a reliable growth curve.

Growth

The seasonal growth in length, plotted for 2-week intervals, is presented in the upper curve of Figure 1, and in Table 1. The increments of growth in length obtained from the curve of growth are indicated in the lower panel of the same figure. Growth in the three year-classes was completed between June and September but differed in each group in that the maximum growth increments occurred at

different periods. In age-group I there was a marked acceleration in growth in July followed by relatively slow growth in August. Age-group III, on the other hand, showed a gradually increasing but relatively slow growth rate in July, but rapid growth occurred in August. Fish of age-group II showed intermediate growth in that they grew more rapidly than age-group III in July and more rapidly than age-group I in August. There was then a progressive change in the period of maximum growth in the three age groups from July in age-group I to August in age-group III. These peculiarities were paralleled by variations in the volumes of the stomach contents of the various age groups.

Table 1.—Average volume of stomach contents in cubic centimeters, average length in millimeters, and average weight in grams of three age groups of yellow perch from Costello Lake in 1397

[Number of individuals indicated in parentheses]

Item	June 1-15	June 16-30	July 1-15	July 16-31	August 1-15	August 16-31	September 1-18
AGE-GROUP I:							
Stomach contents, volumes	.....	0.17	0.69	0.82	0.38	0.70	0.21
	.....	(39)	(29)	(86)	(76)	(35)	(15)
Length	60.0	62.0	65.8	72.6	72.7	74.7	81.7
	(17)	(77)	(32)	(102)	(96)	(31)	(7)
Weight	3.6	3.6	4.2	5.7	5.8	5.9	9.1
	(17)	(77)	(32)	(100)	(99)	(31)	(7)
AGE-GROUP II:							
Stomach contents, volumes	.....	0.18	0.77	1.00	0.79	1.35	.....
	.....	(22)	(41)	(59)	(38)	(14)	.....
Length	81.0	80.0	86.6	91.3	94.6	99.0	95.0
	(23)	(35)	(17)	(50)	(31)	(19)	(9)
Weight	8.2	8.8	10.4	12.1	12.8	13.7	13.2
	(23)	(35)	(17)	(50)	(33)	(21)	(9)
AGE-GROUP III:							
Stomach contents, volumes	.....	1.28	1.12	1.70	2.70	3.19	1.14
	.....	(15)	(18)	(50)	(7)	(68)	(6)
Length	102	105	106	109	114	122	119
	(25)	(13)	(4)	(49)	(12)	(82)	(9)
Weight	17.0	18.2	20.5	20.6	23.1	28.3	25.1
	(24)	(13)	(4)	(49)	(12)	(82)	(9)

Stomach Contents

The average volumes of the stomach contents of each age group (Table 1) analyzed into the proportions of the constituents of the food, are illustrated for bi-weekly intervals in the central or histogram portion of Figure 1. In age-group I there was a marked increase in the volumes of July stomach contents over those for June. This was principally the result of an increase in the amount of *Holopedium* taken. In August the volumes decreased when *Holopedium* was no longer found in the stomachs. Age-group III, on the other hand, showed almost equal amounts of food in June and July but the average volume of their stomach contents increased from 1.7 cubic centimeters in late July to 3.2 cubic centimeters in late August. The

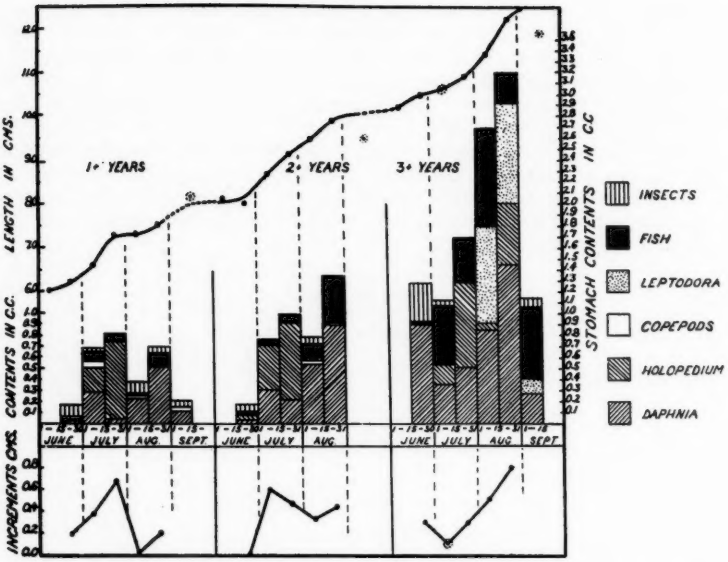

Figure 1.—Average growth in length, volumes of stomach contents with their constituent parts, and increments of growth in length, in 2-week intervals for Costello Lake yellow perch, 1937.

August increase was to a large extent caused by the appearance in the stomachs of large amounts of *Leptodora*, an organism not found in appreciable amounts in the stomachs of individuals of the other two age groups. Age-group II, like age-group I, showed a marked increase in stomach contents from June to July. This was also principally the result of increased amounts of *Holopedium* in the July stomachs. Unlike age-group I, however, there was no decrease in stomach volumes in August, nor was there any marked increase as in age-group III. Thus age-group II was intermediate between age-groups I and III in amount of stomach contents as in growth.

It has been shown that *Holopedium* and *Leptodora* were important in bringing about fluctuations in stomach contents, but other foods made up a large proportion of the bulk of the perch diet. *Daphnia* constituted the greater part of the food in each age-group throughout the season. Insects were also taken by all age-groups and were most important in June and September. Although small fish were taken by all age-groups they became relatively more important in the diet of older perch.

Correlation and Conclusions

Members of age-group I showed their maximum rate of growth in length in July and a decreased rate of growth in August, while the average volumes of their stomach contents varied in a similar manner. Fish comprised by age-group III also showed close agreement between their growth and volumes of their stomach contents, both in July when the growth rate was gradually increasing, and in August, when both growth rate and stomach volumes were at a maximum. Age-group II was found to be intermediate between age-groups I and III both in growth and in seasonal variations in stomach volumes. There was then a close agreement between the seasonal changes in growth and stomach volumes for all age groups.

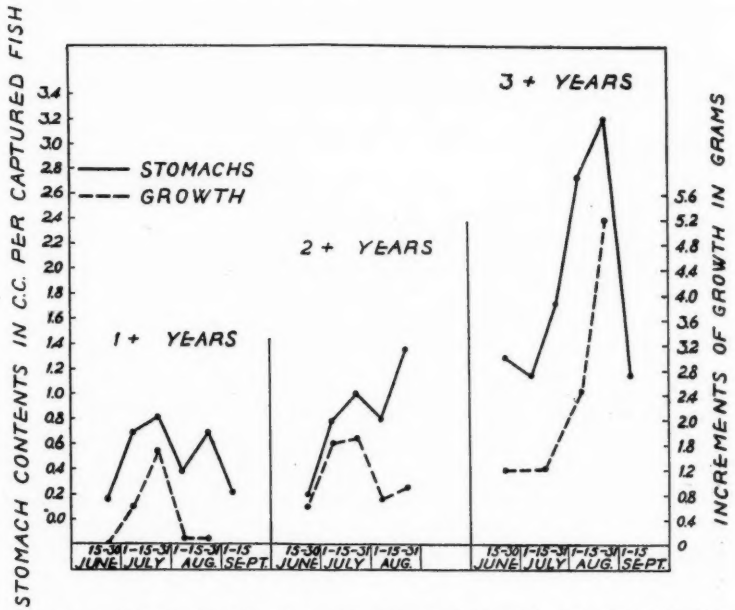

Figure 2.—The relationship of average volumes of stomach contents to biweekly increments of growth in weight in Costello Lake yellow perch, 1937.

The quantitative relationship between growth and food is, however, not clear from the above comparison since a much larger mass of food is required to produce a given increment of growth in length in a large fish than in a small individual. The absolute relationship be-

tween growth and food is made more evident from a comparison of stomach contents with rate of growth in weight (Figure 2 and Table 1). From this comparison it is clear that not only did the trends in the seasonal changes in growth follow those of food but also that there was a very close quantitative relationship between increments of growth in weight and corresponding volumes of stomach contents. This correlation was so well marked in all age-groups, in spite of a shift in the time of maximum increments, that food must surely have been the primary factor controlling growth in this perch population.

Discussion

Dr. A. G. Huntsman: Would the later development of the maximum for the 3-year old fish be correlated with the later development of the larger components of the plankton?

Dr. Langford: Some of the larger plankton elements were so scarce in the lake that it is almost impossible to obtain a quantitative estimate of their numbers so that I do not know when the maximum is reached.

Dr. Huntsman: I note that the *Daphnia* increased. Would the sizes of the *Daphnia* eaten vary with the sizes of the fish?

Dr. Langford: It would be difficult to determine from the stomach contents whether there was a variation or not.

Dr. V. D. Vladykov: You used bread as a bait. Would not the bread attract other organisms as well as the perch so that these organisms might be consumed by the perch while they were in the trap? Would different kinds of bait produce different results?

Dr. Langford: The perch were removed from the trap at frequent intervals; every 4 hours. There was little food in the trap itself.

Dr. C. McC. Mottley: If a differential movement of large and small fish occurs in relation to temperature changes during the year, the growth increments you have obtained might not be representative of the lake as a whole.

Dr. Langford: Other age groups and older fish were also taken. Fish of the three ages studied for this paper were taken as random samples from the lake by minnow traps. In our future studies of the species we will be able to determine the selectivity of both nets and traps from the collections of four or five thousand fish now available. This paper is a preliminary report; scales were examined only to determine ages, and a careful study and measurements of the scales will be made during the continuing investigation in order to answer numerous other questions.

NOTES ON *COSTIA NECATRIX*

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ABSTRACT

Costiasis, or the disease produced by the flagellated protozoan ectoparasite, *Costia necatrix*, is of considerable importance in the artificial propagation of both warm- and cold-water fishes. In spite of its importance, costiasis seldom is accurately diagnosed probably because of the extremely small size and sedentary nature of the causative organism. A general resume of the specific diagnostic characteristics, pathology, and recommended measures for the prevention and control of *Costia necatrix* are presented. The application of available information concerning the parasite may eliminate effectively the losses of fish in hatcheries occasioned by it.

No parasite commonly found on hatchery fishes appears to escape detection as easily as *Costia necatrix*. Because of its extremely small size and sedentary habits, even well-trained observers often fail to recognize severe infestations. Costiasis, or the disease produced by *Costia necatrix*, is of serious consequence to pond fishes and to salmon and trout as well. A general review of the known facts concerning *Costia necatrix* and costiasis might prove of timely assistance to the proper and adequate recognition of this parasite. In the preparation of this review, the author has drawn freely upon the literature as well as personal experiences and observations.

Costia necatrix was described originally by Henneguy (1883) as *Bodo necator*. Later, the parasite was relegated to the genus *Costia*, created for it by LeClerq (1890). At the present time, the genus *Costia* contains but the single species *necatrix*. Many workers have made taxonomic and morphological contributions to the knowledge of *Costia necatrix*, perhaps the most outstanding being those of Moroff (1904) and Andai (1933). The reader is referred to the publication of Andai for an excellent review of existing literature on *Costia necatrix* as well as original morphological studies on this parasite as it is found in Europe.

Stained and mounted material collected during investigations of costiasis by the Fish and Wildlife Service in the Pacific Northwest was found to exhibit less variation in size than was encountered by Andai although the mean values of all dimensions were well within the expected variation which he specified. Measurements from 200 parasites, fixed in hot Schaudinn's fluid and stained in Heidenhain's iron-hematoxylin, yielded an average mean length of 7.85 microns (standard deviation, 0.76 microns) and a mean breadth of 5.12 microns (standard deviation, 0.32 microns). Similar mathematical treatment of data obtained by Andai from 94 parasites (exclusive of four-flagel-

lated dividing forms), similarly fixed and stained, yielded a mean length of 9.63 microns (standard deviation, 2.01 microns) and a mean breadth of 7.49 microns (standard deviation, 2.21 microns). The organism encountered on the Pacific Coast has varied in no significant detail from the description of *Costia necatrix* as given by Andai and others, and therefore has been assumed to belong to the same genus and species.

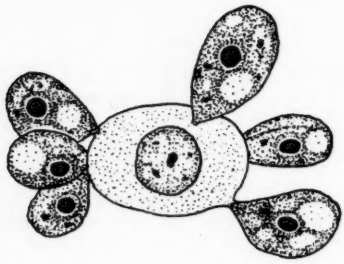

Figure 1.—Six trophozoites of *Costia necatrix* attached to a single epithelial cell. Sketched from photomicrograph of epithelial smear stained with iron hematoxylin. (Magnification, 2,500 diameters.)

Two phases of *Costia necatrix* usually are encountered in epithelial smears of living material: Parasites attached to epithelial cells of the host, and a much smaller number of free-swimming forms. The attached forms of *Costia necatrix* are definitely pear-shaped in outline and flattened dorso-ventrally, particularly at the blunt anterior end. The attached forms usually assume a slight twist giving them a characteristic comma-like apperance. The free-swimming forms are ellipsoid in outline but similarly compressed. Few structural details can be discerned in the living parasites. *Costia necatrix* can be detected by an experienced observer under the standard low-power magnification (100 diameters) although the use of a higher magnification (430 diameters) is advisable for confirmation.

When the parasites are properly fixed and stained, one or more large vacuoles, various short, blunt, deeply staining cytoplasmic inclusions, and a nucleus composed of a spherical or subspherical solid block of chromatin, measuring 1.9 microns in diameter and surrounded by a clear halo, are easily discerned. On the free-swimming forms, two flagella of unequal length will be observed which arise from small indistinct blepharoplasts in the anterior end of the parasite, lie along a definite funnel-shaped groove in one (the ventral) side of the organism, and then extend two to three times the body length beyond the body of the organism. Occasionally, somewhat larger individuals are observed which possess two additional short flagella which lie within the ventral groove and do not extend beyond the body. Most workers have regarded these unusual forms as a stage immediately preceding division. Flagella never are seen about the attached forms

which has given rise to the general belief that the flagella are in some way utilized to affix the parasite to the host cell. The exact mechanism of attachment has not been determined.

As many as 15 parasites have been observed attached to a single epithelial cell. Judging from the cellular hyperplasia which accompanies infestations of *Costia necatrix*, considerable irritation and probable eventual death to the parasitized epithelial cell are produced. The vigorous scratchings of infested fish leave little doubt as to the degree of irritation produced by the parasite.

No parasites are likely to be encountered which will be confused with the attached forms of *Costia necatrix*, although an occasional epithelial cell produced in the irregular hyperplasia may superficially resemble an attached parasite. In general outline, the attached forms of *Costia necatrix* resemble a *Scyphidia*-like ciliated protozoan occasionally observed on the body and gill filaments of trout (Figure 2). An experienced observer will have little difficulty in distinguishing between the two as *Costia necatrix* is approximately one-tenth the size of the latter.

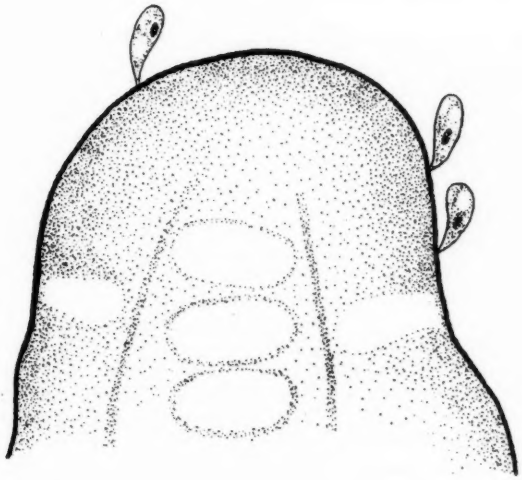

Figure 2.—Trophozoites of *Costia necatrix* showing typical appearance when attached to the epithelium at the tip of a gill filament. Sketched from photomicrograph of unstained formalin-preserved material. (Magnification, 2,000 diameters.)

The free-swimming forms of *Costia necatrix* are easily confused with the trophozoites of *Octomitus salmonis* in fresh preparations. Unless extreme care is exercised to preclude contamination of preparations by fecal material expressed from the vent through the pressure exerted in obtaining an epithelial smear, both parasites may be observed in the same slide. Although very similar in outline, *Costia necatrix* is slightly smaller than *Octomitus salmonis*. The most reliable differential criteria are the characteristic swimming motions of the two parasites and their respective shapes in cross section. *Costia necatrix* swims in a hesitating fashion whereas *Octomitus salmonis* proceeds with a smooth uniform motion. *Costia necatrix*, being dorso-ventrally compressed, is flattened in cross section whereas *Octomitus salmonis* is definitely circular. Red blood cells, being quite uniform in size and present in most preparations, offer a handy microscopic yardstick for rough comparative measurements of parasites. Trophozoites of *Octomitus salmonis* are roughly the same size as a red blood cell and those of *Costia necatrix* are definitely smaller.

Costiasis may be found at any time among fingerling fish although in salmon and trout, at least, the most severe epidemics seem to appear within a few weeks after the time of first feeding. The disease seldom is of material consequence among fish larger than No. 2 fingerlings.

Fish affected by costiasis exhibit no characteristic symptoms specific to this disease. As common to all infestations by external parasites, the first indications of costiasis are a diminution in appetite accompanied, or immediately followed, by "flashing" produced by the fish scratching on the bottom and sides of confining equipment. A progressive rise in the daily mortality rate soon ensues. In advanced untreated cases, the fish may assume a blue-grey cast which is produced by a marked general hyperplasia of the body epithelium apparently as a defense mechanism of the host against the irritation produced by the parasite. The cellular reaction to the irritation of *Costia necatrix* is likewise exhibited by the gill epithelium wherein tissue alteration comparable to the earlier stages of gill disease may be produced which undoubtedly handicaps the normal processes of respiration.

The specific diagnosis of costiasis necessitates identification of *Costia necatrix* through microscopical examination. In general, two areas of the body offer the most probable sources of *Costia necatrix*: The epithelium in the immediate vicinity of the dorsal fin, and the gill filaments. Epithelial smears or gill arches, isolated by dissection, should be mounted in physiological (0.65 per cent) salt solution although even this precaution will not prolong the life of the parasite on a microscope slide much longer than 5 minutes. Smears for immediate examination may be mounted in water. In advanced cases, hundreds of parasites—most of which are attached—may be observed in epithelial preparations. In the gill preparations, fewer parasites are encountered although those present usually appear less distorted and are

more easily recognized. The parasite attaches itself to the gill epithelium near the tips of the filaments. The attached forms of *Costia necatrix*, particularly those on the gill epithelium, may be recognized on formalin-preserved material as easily as on living tissues.

Costiasis may be eradicated effectively by a single 1-hour prolonged treatment with a 1:4,000 solution of formalin. At hatcheries where constant trouble is occasioned by recurring attacks of costiasis, the appearance of the disease may be prevented by routine prolonged treatments with formalin, 1:6,000, administered at bi-weekly intervals during the period when costiasis is anticipated. As a general precautionary measure against the appearance of *Costia necatrix*—and other common external parasites as well—at trout and salmon hatcheries, bi-weekly 1-hour treatments in 1:6,000 formalin are recommended from the time the fry are actively feeding until they have attained the No. 2 fingerling stage. Contra-indications of prolonged formalin treatments are any type of gill disease and obvious anemia. For details concerning the effective prophylaxis and therapeusis by means of prolonged formalin treatments, the reader is referred to the publications of Fish (1940, 1940a) and Fish and Burrows (1940).

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RESULTS FROM PLANTINGS OF MARKED TROUT OF LEGAL SIZE IN STREAMS AND LAKES OF MICHIGAN[1]

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ABSTRACT

Intensive creel censuses served as the chief basis for estimates of the effectiveness of plantings of marked legal-sized brook trout, brown trout and rainbow trout at various seasons over a period of from 1 to 3 years in sections of five public streams and in two private streams. Similar data are presented for plantings of rainbow trout in five lakes. Returns from fall planting in streams never exceeded 5.3 per cent; spring and open-season plantings resulted in the recovery by anglers of from 4.9 to 61.9 per cent of the fish released. Fall plantings of rainbow trout in lakes yielded returns up to 66 per cent. Plantings of from 100 to 160 trout per mile of stream averaging 50 feet in width yielded higher percentage returns than did plantings of larger numbers of fish, benefited relatively more anglers, and did not stimulate the catch of native fish. The increase in the catch per hour and the percentage of hatchery fish in the total catch appeared to be inversely proportional to the density of the native population of the species stocked and directly proportional to the number of fish planted. The percentage of the total catch contributed by plantings of moderate numbers of trout in the spring or during the season varied from 1.8 to 30.4. It is concluded that in northern Michigan streams, major dependence for good fishing must be placed on the native or "wild" stock. Rainbow trout and brown trout were caught for at least 8 weeks following planting, although the majority was removed by the end of 4 weeks; few if any brook trout were taken after 4 weeks. Very few planted trout survived one or more winters even in private streams not subject to intensive angling. Most of the trout were taken within 5 miles of the point of release and usually downstream; of the three species, rainbow trout migrated most extensively. From 5.7 to 20.6 per cent of the fisherman-day records showed the capture of marked trout. Apparently as many anglers benefited from "spot" plantings as from wider distribution by boat. Control experiments proved that jaw-tagging and fin-clipping provided effective methods of tracing fish during the period of investigation and that mortality and the effect on growth of either method were negligible.

INTRODUCTION

The results of earlier experiments (Hazzard and Shetter, 1939) led to the expansion of a research program initiated in 1937 to determine the returns to the angler from plantings of legal-sized trout[2] in Michigan waters. Creel censuses were carried out on sections of four additoinal public streams in which plantings of tagged or fin-clipped brook trout (*Salvelinus fontinalis*), rainbow trout (*Salmo irideus*) and brown trout (*Salmo trutta*) were made in fall, early spring, and during the fishing season. Similar data from two private streams and from several trout lakes also are included in the present paper.

[1]Contribution from the Michigan Institute for Fisheries Research.
[2]In Michigan, the minimum legal size for brook trout, brown trout, and rainbow trout is 7 inches (total length).

The discussion of the results from plantings of marked trout will be confined to the percentage of fish in the plantings taken by anglers, the proportion of hatchery fish in the catch and a comparison of results from two methods of planting. Detailed data on growth and migration of planted trout will be presented in a later publication.

Methods

Methods employed during 1938 and 1939 were essentially the same as those described previously (Hazzard and Shetter, 1939). Briefly, they consisted of planting jaw-tagged or fin-clipped trout, 7 inches or more in length, in sections of five trout streams and four small lakes which were covered by intensive creel censuses. Crews of trained census clerks, in charge of a qualified biologist, camped at strategic locations on the Pine River and secured records of almost all of the fishing in the sections in which the trout were planted. On all other public streams and on the lakes, C.C.C. enrollees conducted creel censuses under the supervision of staff members of the Institute.

All of the trout used in the experiments during 1938 and 1939 were either fin-clipped or jaw-tagged and were supplied by and planted from the most conveniently located hatchery. The senior author did the marking and assisted in distributing almost all of the fish used.

Results of Similar Tagging Experiments in Other States

Cobb (1934), who described experiments conducted in Connecticut in 1933, reported recoveries of 5,403 (33 per cent) of 15,875 tagged legal brown trout and brook trout. Cobb used the internal tag. His results indicated rapid depletion, usually within a week, of the brook trout released during the season, but demonstrated that the brown trout provided fishing over a longer time. Of the fish recovered, 80 per cent of the brook trout and 66 per cent of the brown trout were recaptured near the point of planting. Cobb stated also that fall plantings of legal trout in Connecticut waters had failed to overwinter, but offered no data on this point.

Nesbit and Kitson (1937), working in Massachusetts, made releases of legal-sized brown trout and rainbow trout in the fall of 1934 and the spring of 1935. All fish were tagged with the internal tags. They concluded that the spring planting was more efficient than fall planting by an average ratio of 5 to 1, and the ratio was as high as 10 to 1 for streams. For ponds also, they concluded that the spring planting was more efficient than fall releases, but the advantage appeared to be only slightly more than 2 to 1.

Hoover and Johnson (1938) planted legal brook trout in New Hampshire streams in 1936, marking them with a paper clip on the gill cover and releasing the marked fish during the open season. A recovery of 76 per cent was made within 3 weeks after planting—an-

other indication of the rapid depletion of planted fish released during the open season.

Results of Marking Experiments in Public Streams of Michigan

Percentage of planted trout caught.—The percentage of hatchery brook trout from various plantings caught during the 3 years of census (Tables 1 to 3) varied from 2.0 to 58.4; for rainbow trout from 0.6 to 61.9; for brown trout from 2.0 to 19.2. All percentages of fish recaptured must be considered minimal since a few records undoubtedly were missed and some catches of marked fish outside census areas probably were unreported.

Relatively high recovery percentages were noted in the Pine River from plantings made during June and July of 1938 and 1939. Just why a release of 250 brook trout in July, 1939, should yield better returns than one of 488 planted in June, 1939, cannot be explained (Table 3).

Table 1.—Summary of recoveries by anglers of marked and unmarked hatchery trout of legal size available during the 1937 trout season

Date of planting (1937)	Species of trout planted	Number planted	Method of marking and proportion marked[1]	Recoveries (1937)[2]		Percentage of total catch
				Number	Percent.	
			PINE RIVER			
May 18-19	Brook	3,000	1/3 tag	1,207	40.2	38.1
June 15	Brook	959	All tag	58	6.0	1.8
	Rainbow	2,007	½ tag	448	22.3	34.4
July 13	Brook	2,004	¼ tag ¼ dorsal	98	4.9	3.1
	Rainbow	1,000	¼ tag ¼ dorsal	102	10.2	3.1
Aug. 10	Brook	1,550	1/3 tag 1/3 dorsal	125	8.1	3.9
	Rainbow	1,000	¼ tag ¼ dorsal	136	13.6	4.1
Total brook trout		7,513	.....	1,488	19.8	46.9
Total rainbow trout		4,007	.....	686	17.1	20.6
			PIGEON RIVER			
August 4	Rainbow	985	½ tag ½ dorsal	148	15.0	25.0

[1]Where fin is named, this fin and the adipose fin were removed.
[2]In the Pine River, the numbers of hatchery fish taken were calculated from the percentage of marked fish planted, and the actual numbers of marked trout retaken by anglers.

In the Pigeon River, the best returns were from the plantings made in June, 1939. The releases of both brown trout and rainbow trout in July, 1939, were almost failures. The fact that 12 of the 17 marked brown trout recovered were found dead about 10 days after planting, suggests that the water temperature may have been too high for successful introduction at that time of the year. A similar mortality of the tagged brown trout occurred in late June and early July in the

Table 2.—Summary of recoveries by anglers of marked hatchery trout of legal size available during the 1938 trout season

Date of planting	Species of trout planted	Number planted	Method of marking[1]	Recoveries—1938		Recoveries—1939		Percentage of total catch	
				Number	Percentage	Number	Percentage	1938	1939
PINE RIVER									
Oct. 1937	Brook	1,000	Tag	53	5.3	....	....	2.6	....
	Rainbow	500	Tag	6	1.2	....	....	0.6	....
Apr., 1938	Brook	1,000	Tag	349	34.9	1	0.1	14.9	0.03
	Rainbow	500	Tag	192	38.4	3	0.6	3.1	0.03
May, 1938	Brook	500	Tag	516	51.6	1	0.1	21.9	0.03
	Brook	500	Left pelvic						
	Rainbow	500	Tag	441	44.1	5	0.5	7.2	0.05
	Rainbow	500	Left pelvic						
July, 1938	Rainbow	500	Tag	236	[2]59.0	7	1.4	3.9	0.08
Total brook trout		3,000	.....	918	30.7	2	0.1	39.5	0.10
Total rainbow trout		2,500	.....	875	35.0	15	0.6	14.8	0.10
CANADA CREEK									
Mar., 1938	Brook	500	Tag	180	36.0	....	....	[3]18.2	....

[1]Where fin is named, that fin and the adipose fin were removed.

[2]This recovery percentage has been calculated on the basis of recoveries from 400 tagged fish released within the area covered by creel census.

[3]The percentage of the total catch consisting of marked brook trout was calculated on the basis of 140 recoveries made within the creel census area.

Table 3.—Summary of recoveries by anglers of marked hatchery trout of legal size available during the 1939 trout season

Date of planting	Species of trout	Number planted	Method of marking[1]	Recoveries (1939)		Percentage of total catch (1939)
				Number	Percent.	
AU SABLE RIVER (North Branch)						
Nov., 1938	Brook	500	Tag	32	6.4	1.7
	Brook	500	Right Pelvic	12	2.4	0.6
Mar., 1939	Brook	500	Tag	119	23.8	5.8
	Brook	500	Left pelvic	28	5.6	1.5
Total		2,000		[2]241	12.1	[2]11.8
PINE RIVER						
Nov., 1938	Brook	499	Tag	5	1.0	0.3
	Brook	299	Right pectoral	11	3.7	0.8
Apr., 1939	Brook	500	Tag	207	41.2	14.4
	Brook	300	Left pectoral	73	24.3	5.2
June, 1939	Brook	488	Tag	114	23.2	7.9
	Rainbow	249	Tag	154	61.9	2.6
July, 1939	Brook	250	Tag	146	58.4	10.2
	Rainbow	250	Tag	150	60.0	2.5
Total brook trout		2,336	.....	[3]571	26.2	[3]39.8
Total rainbow trout		499	.....	307	61.5	5.2
PIGEON RIVER						
Nov., 1938	Brown	500	Tag	16	3.2	7.3
	Rainbow	500	Tag	3	0.6	0.5
Apr., 1939	Brown	500	Tag	34	6.8	15.5
	Rainbow	500	Tag	50	10.0	8.0
June, 1939	Brown	250	Tag	39	15.6	20.1
	Rainbow	250	Tag	61	24.4	9.0
July, 1939	Brown	250	Tag	5	2.0	2.3
	Rainbow	250	Tag	20	8.0	3.2
Total brown trout		1,500	.....	94	6.3	45.2
Total rainbow trout		1,500	.....	134	8.9	20.7
LITTLE MANISTEE RIVER						
June, 1939	Brown	250	Tag	48	19.2	17.2
July, 1939	Brown	250	Tag	38	15.2	14.2
	Brook	250	Tag	81	32.4	30.4
Total brown trout		500	.....	86	17.2	15.7
Total brook trout		250	.....	81	32.4	30.4

[1]Where fin is named, that fin and the adipose fin were removed.

[2]Fifty fish added to obvious total; these fish were fin-clipped but fin was not distinguished by creel census clerks.

[3]Fifteen marked brook trout with tag or mark not distinguished were added to totals.

Little Manistee River. However, in the latter stream anglers reported the death of a number of unmarked brown trout and rainbow trout that were not from these plantings.

The averages by seasons of planting (Table 4) are most significant. Data for brown trout and for fall and spring releases of rainbow trout probably are not adequate for definite conclusions. Experiments are planned this year to supply additional information. However, according to our results and those of the other workers mentioned previously, plantings of brook trout and rainbow trout yield about the same returns to the angler but fewer brown trout are caught. Whether this difference is due to a heavier mortality of planted brown trout or to their greater ability to escape capture has not been determined.

Table 4.—Summary of results from plantings of marked legal-sized brook trout, brown trout, and rainbow trout in Michigan trout streams, in fall, early spring (pre-season), and during the open trout season, 1937 to 1939, inclusive

Species	Fall releases			Spring releases			Open-season releases		
	Number of experiments	Number of fish planted	Percentage recovered	Number of experiments	Number of fish planted	Percentage recovered	Number of experiments	Number of fish planted	Percentage recovered
Brook trout (totals and averages for 4 streams)	3	2,798	4.4	4	3,300	29.8	8	9,501	24.7
Rainbow trout (totals and averages for 2 streams)	2	1,000	0.9	2	1,000	24.2	10	7,391	25.7
Brown trout (totals and averages for 2 streams)	1	500	3.2	1	500	6.8	4	1,000	13.0
All trout (totals and averages for 5 streams)	6	4,298	3.4	7	4,800	26.2	22	17,892	24.5

Time of planting.—The season of 1938 yielded the first comparable results of fall, early spring (pre-season), and open-season plantings in the Pine River. The percentage of recovery of brook trout planted in the spring was over six times greater than that of brook trout planted in the fall; the percentage of rainbow trout recovered from spring plantings was 32 times the percentage recovered from fall plantings (Table 2). During the fall of 1938 and the spring of 1939, equal numbers of legal-sized marked brook trout were planted in each season in the North Branch of the Au Sable River and in the Pine River, and equal numbers of marked rainbow trout and brown trout were planted in the Pigeon River (Table 3). Again spring planting was found to be much more efficient than fall planting. The averages for brook trout were 4.4 and 29.8 per cent for fall and spring plantings, respectively; for rainbow trout the percentages were 0.9 and 24.2; and for brown trout the percentages were 3.2 and 6.8 (Table 4). The one experiment with brown trout indicated less difference between the results from the plantings in the two seasons.

Plantings of brook trout during the open fishing season appear to be slightly less efficient than plantings made in early spring. No significant difference is apparent in the returns of rainbow trout planted in the two seasons. Limited data for brown trout favor plantings during the open season.

Number of fish in plantings.—The percentages of recovery following plantings of from 500 to 3,000 trout at each camp ground on the Pine River indicate that, on the average, the smaller the number of trout released the higher the percentage caught (Tables 1-3). From

100 to 160 trout per mile of stream averaging 50 feet in width yielded to fishermen returns of from 23.2 to 61.9 per cent. Furthermore, the lighter stocking in 1938 and 1939 benefited a somewhat larger number of fishermen (Table 7) and contributed to the catch for a longer period. Also, as will be shown later, smaller plantings did not cause depletion of the "wild" stock.

Method of planting.—In 1937 and 1938 two methods of distribution were tested in the Pine River (Table 5). "Spot" planting, the usual method, consisted of scattering the fish over from one-fourth to one-half mile of stream adjacent to each camp ground. In boat planting, a specially constructed metal boat with a center well was used to place a few trout in each pool of the section of stream stocked. Results from this phase of the experimental work are not conclusive as both methods were not employed simultaneously over the same water and the marked fish released in the two manners were not subject to the same angling pressure.

Table 5.—Comparison of results from "spot" and "boat" plantings of trout in the Pine River, 1937 to 1939 (Data from spring and open-season plantings combined)

Item	1937		1938		1939	
	Brook trout	Rainbow trout	Brook trout	Rainbow trout	Brook trout	Rainbow trout
Number of trout spot-planted	1,000	1,007	1,000	1,000	1,538	499
Number of trout boat-planted	2,963	1,000	1,000	1,000	.....	.....
Number of anglers taking spot-planted trout	96	75	225	353	330	243
Number of anglers taking boat-planted trout	69	61	187	290	.....	.....
Number of spot-planted trout caught	402	224	296	422	555	307
Percentage	40.2	22.3	29.6	42.2	36.0	61.5
Number of boat-planted trout caught	161	119	516	441	.....	.....
Percentage	5.4	11.9	51.6	44.1	.....	.....
Average number of spot-planted trout caught per angler	4.2	3.0	1.3	1.2	1.6	1.3
Average number of boat-planted trout caught per angler	2.3	2.0	2.8	1.5	.....	.....

More anglers took "spot-planted" than "boat-planted" fish (both brook trout and rainbow trout) in 1937 and 1938. (No boat plantings were made in 1939.) A higher percentage of spot-planted fish was taken in 1937, but in 1938 a higher percentage of boat-planted trout was captured. The average number of trout caught from spot plantings was the higher in 1937, but the average was the higher for boat plantings in 1938. Probably the smaller size of the plantings in 1938 may have been responsible for these changes since the fish were not

as concentrated and limit catches of marked trout were not as common.

Effect upon the catch.—The influence of the planted fish on the total catch may be seen by comparing the percentage of the catch of the various species that consisted of hatchery trout (Table 6). In the Pine River, planted brook trout made up from 40 to 47 per cent of the total catch of brook trout, whereas planted rainbow trout made up only from 5 to 21 per cent of the total catch of rainbow trout in the years 1937 to 1939, inclusive. In the Pigeon River, although marked

Table 6.—Percentage of native and planted trout in the total catch of the species planted in several Michigan trout streams

Stream	Year	Type and species of trout	Percentage of total catch
Pine River	1937	Native brook	53
		Planted brook	47
		Native rainbow	79
		Planted rainbow	21
	1938	Native brook	61
		Planted brook	39
		Native rainbow	85
		Planted rainbow	15
	1939	Native brook	60
		Planted brook	40
		Native rainbow	95
		Planted rainbow	5
Pigeon River	1937	Native rainbow	75
		Planted rainbow	25
	1939	Native rainbow	79
		Planted rainbow	21
		Native brown	55
		Planted brown	45
North Branch, Au Sable River	1939	Native brook	88
		Planted brook	12
Canada Creek	1938	Native brook	82
		Planted brook	18
Little Manistee River	1939	Native brook	70
		Planted brook	30
		Native brown	65
		Planted brown	35

adult rainbow trout were not released until August, 1937, with less than a month of the season remaining, the total number of marked fish recovered constituted 25 per cent of the total catch of that species. During 1939 the percentages of native and hatchery fish in the total catch of the Pigeon River ran as follows:

Native rainbow trout	79.3 per cent
Planted rainbow trout	20.7 per cent
Native brown trout	54.8 per cent
Planted brown trout	45.2 per cent

Marking experiments and creel-census data from the North Branch of the Au Sable River for the 1939 trout season showed that the total catch of brook trout consisted of 12 per cent marked (hatchery) brook trout and 88 per cent native brook trout. It should be pointed out that the planting of 2,000 legal-sized trout for the 1939 season yielded many more fish to the anglers than did the release of 9,778 fingerlings (averaging 3.5 inches long) in the fall of 1936. Of the latter planting, only three fish were recorded in the creel census during the 1937 and 1938 trout seasons (Shetter, 1939). However, the catch per hour fell from 0.48 trout in 1938 to 0.41 in 1939, despite the addition of 2,000 legal brook trout.

The recoveries (140) from the single planting of 500 tagged adult brook trout in Canada Creek in March, 1938, constituted 18 per cent of the total catch of brook trout, while the remaining 82 per cent originated from native stock and plantings of fingerlings. In the Little Manistee River during the 1939 trout season, recoveries from plantings of tagged fish constituted 30 per cent of the total catch of brook trout, and 34 per cent of the total catch of brown trout.

In no instance have the marked fish released in the fall (Tables 2, 3) contributed more than 7 per cent of the total catch of that species during the next season. The hatchery trout contributing to the total catch of the three species of trout were almost always those that were released in the spring or during the open season.

The differences in the percentages of the total catch consisting of planted adult trout reflect, to a large degree, the relative natural abundance of the several species of trout in the various streams under consideration. The Pine River, for example, is dominantly rainbow-trout water in the 10-mile section where the experiments were conducted. Releases of smaller numbers of marked rainbow trout in 1939 were literally lost among the numerous native fish. Native brook trout were less abundant, and consequently the introduction of marked hatchery brook trout contributed noticeably to the total catch of that species in the Pine River.

In an earlier paper (Hazzard and Shetter, 1939) it was shown that monthly introductions of approximately 2,000 brook trout and 1,000 rainbow trout of legal size during the 1937 trout season increased the catch per hour of native fish immediately following planting to two or three times that recorded for weeks just previous to planting. A similar rise in the catch per hour of native fish occurred after a release of 985 marked adult rainbow trout in the Pigeon River in August, 1937 (Figs. 1 and 2).

In the 1938 trout season, the catch per hour of native brook trout during the opening week on the Pine River was approximately the same as in 1937, despite the introduction of 1,000 tagged brook trout (all of legal size) one month before the opening of the season. Possibly competition for food was less severe at that time of year or some trout had moved out of the area in which the planting was made by

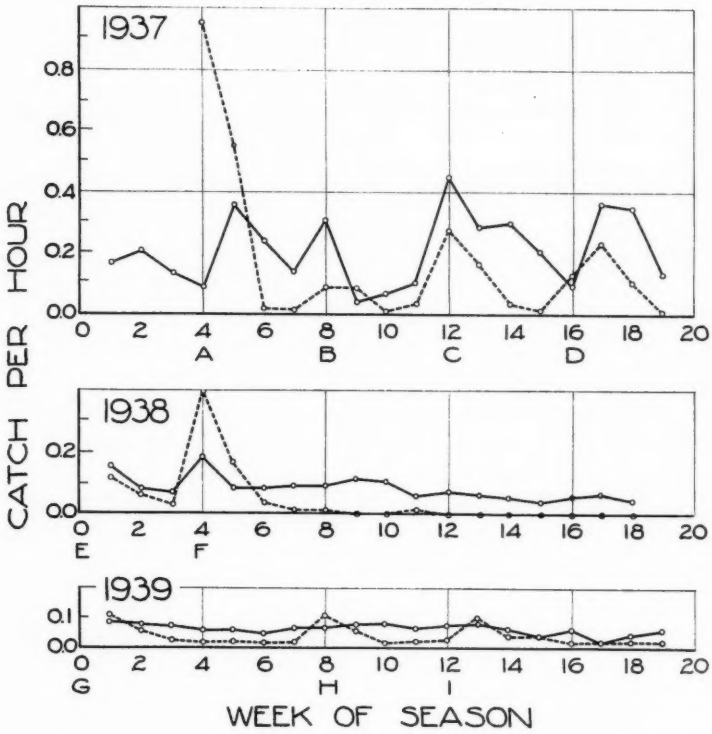

Figure 1.—Catch per hour of native, ———, and hatchery, — — —, brook trout in the stream section under creel census on the Pine River, Michigan, for the 1937, 1938, and 1939 trout seasons. Plantings E and G were made 4 weeks prior to the opening of the season.

A—3,000 fish planted
B— 959 fish planted
C—2,004 fish planted
D—1,550 fish planted
E—1,000 fish planted
F—1,000 fish planted
G— 800 fish planted
H— 488 fish planted
I— 250 fish planted

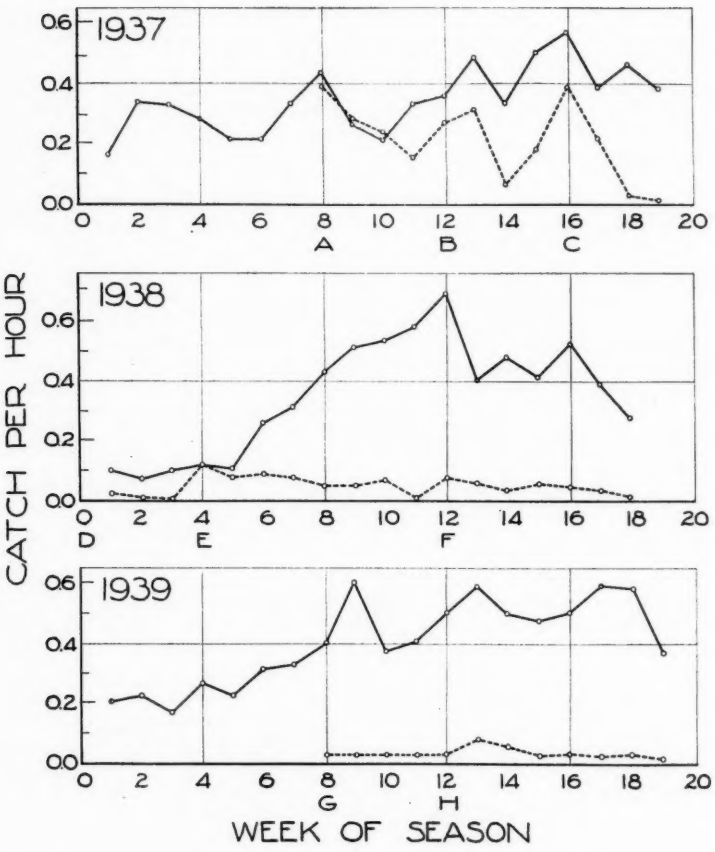

Figure 2.—Catch per hour of native, ———, and hatchery, — — —, rainbow trout in the stream section under creel census on the Pine River, Michigan, for the 1937, 1938, and 1939 trout seasons. Planting D was made 4 weeks prior to the opening of the season.

A—2,007 fish planted
B—1,000 fish planted
C—1,000 fish planted
D— 500 fish planted
E—1,000 fish planted
F— 400 fish planted
G— 249 fish planted
H— 250 fish planted

the opening of the season. The planting of 1,000 marked brook trout during the fourth week of the season, as in 1937, stimulated the catch perhour of native fish for the fourth week from 0.06 to 0.18. Again, as during 1937 and with the spring planting in 1938, the influence of the planting on the catch of native fish was lost within 2 weeks.

The numbers of fish in plantings of marked adult rainbow trout also were reduced during the 1938 investigations on the Pine River. Five hundred fish were released one month before the opening day, 1,000 were introduced during the fourth week of the season, and 500 more were planted in the twelfth week. There were slight increases in the catch per hour of native fish during the periods after the rainbow trout wre introduced, but these increases were of such small magnitude as to be of doubtful significance (Figs. 1 and 2).

In the Pine River during 1939 the plantings of marked brook trout and rainbow trout varied from 250 to 800 fish. These plantings of comparatively small numbers of fish exerted little if any influence on the catch per hour of the native brook trout or rainbow trout (Figs. 1 and 2).

The relative effect of the introductions of hatchery trout on the quality of the fishing as well as on the total catch is dependent on the relative abundance of the native and introduced fish of the species (Table 7). For example, the relatively small number of rainbow trout planted had little effect on the total catch per hour of that species in the Pine River where the native population of rainbow trout is comparatively large. However, the catch per hour of brook trout, a species that is considerably less abundant naturally in that stream than is the rainbow trout, usually was increased by plantings to almost double that obtained for native fish alone. In general, plantings of marked hatchery fish in the several streams have contributed from 8 to 25 per cent of the total catch per hour.

Table 7.—The effect of plantings of hatchery trout on the quality of the fishing as measured by the catch per hour

Item	Kind of trout	Stream								
		Pine River			Pigeon River		North Branch, Au Sable River		Little Manistee River	Canada Creek
		1937	1938	1939	1937	1939	1938	1939	1939	1938
Total catch per hour		0.77	0.50	0.49	0.48	0.48	0.48	0.41	0.37	0.41
Catch per hour of brook trout	Native	0.20	0.08	0.06	0.30	0.35	0.39	0.30	0.07+	0.33
	Planted	0.18	0.06	0.04	.....	.....	.....	0.04	0.04+	0.07+
Catch per hour of rainbow trout	Native	0.31	0.31	0.37	0.10	0.07	0.02	.....	0.14+	.....
	Planted	0.08	0.05	0.02	0.04	0.02	.....	.....	.....	.....
Catch per hour of brown trout	Native	.....	.....	.....	0.04	0.02	0.07	0.07	0.07+	0.00+
	Planted	.....	.....	.....	.....	0.02	.....	.....	0.04+	.....
Total number of hatchery trout available	Brook	7,513	3,000	2,336	.....	.....	.....	2,000	250	500
	Rainbow	4,007	2,500	499	985	1,500	.....	.....	.....	.....
	Brown	.....	.....	.....	.....	1,500	.....	.....	500	.....

Percentage of anglers benefited.—The percentage of anglers fishing streams covered by creel census who took marked trout was consistently low (Table 8), ranging from 20.6 on the Pine River in 1938 to 5.7 on the North Branch of the Au Sable River in 1939. These percentages suggest rather forcefully that only a small fraction of the trout-fishing public benefits from what might be considered as heavy plantings of adult trout and that in these streams, the native stock furnishes most of the fishing. The local fishermen who find out when plants have been made, and the fortunate tourists who happen to fish stream sections where plantings have just been made, take most of the hatchery fish.

Table 8.—Distribution of the catch of hatchery trout among anglers on the Pine River and other streams covered by creel census in 1937, 1938 and 1939

Item	River and year						
	Pine			North Branch, Au Sable	Pigeon	Little Manistee	Canada Creek
	1937	1938	1939	1939	1939	1939	1938
Total number of anglers[1]	2,010	4,109	3,933	2,107	2,213	491	494
Number of anglers taking hatchery fish	229	847	523	118	147	60	64
Percentage of anglers taking hatchery fish	11.4	20.6	13.3	5.7	6.6	12.3	12.9
Total number of hatchery trout available	5,970	5,500	2,835	2,000	3,000	750	500
Total number of hatchery trout recaptured	906	1,825	869	228	228	160	140
Average number of hatchery trout taken by anglers taking marked trout	4.0	2.2	1.7	1.9	1.6	2.7	4.6
Range in number of hatchery trout in creels	1-[2]16	1-15	1-11	1-10	1-7	1-15	1-11

[1]Figures are actually for "fisherman-days" and not for individual fishermen. For example, if one man fished two days on any stream he was recorded as two fishermen.

[2]Although the legal limit is 15 trout, one fisherman was found to have 16 marked trout in his possession.

Duration of the effect of plantings.—The findings of others concerning the rate of removal of legal-sized fish are confirmed by results in Michigan. The results secured on the Pine River during 1938 and 1939 were essentially the same as those reported in an earlier paper (Hazzard and Shetter, 1939). The bulk of the catch of hatchery brook trout was taken within the first 2 weeks after stocking, while marked rainbow trout and brown trout contributed to the catch in fair numbers for at least 8 weeks after release. By the end of the fourth week from 67 to 100 per cent (average 92 per cent) of the hatchery trout recovered had been taken. Results from releases of marked brook trout in other streams were similar.

Plantings of rainbow trout usually contributed to the catch for a much longer period than did plantings of brook trout. In the three years of the Pine River census, from 34 to 100 per cent (average 67

per cent) of the season's catch of hatchery rainbow trout were removed by the end of the fourth week. On the Pigeon River hatchery rainbow trout were removed at about the same rate in both 1937 and 1939.

If the results on a single stream are representative, brown trout may be expected to survive longer than either brook trout or rainbow trout. At the end of 4 weeks from 30 to 100 per cent of the catch of hatchery fish were recorded (average 51 per cent). Brook trout and rainbow trout from the smaller plantings of marked fish made during 1938 and 1939 were caught for a longer period than were fish from the larger plantings made in the preceding year.

Migration.—Most of the brook trout were caught within 5 miles of the point of release, but in contrast to results from the Pine River in 1937, reported by the authors in 1939, the trend of the limited movement was downstream. Brown trout migrated even less. In no case did the movement of marked brown trout exceed 5 miles in any direction with the exception of brown trout from a planting in Kinne Creek, a few of which descended into the Pere Marquette River. Rainbow trout, however, tended to move considerably farther and in larger numbers. The movement which was generally downstream was particularly noticeable in the Pigeon River, where several tagged fish were taken over 15 miles from the points of release.

Results of the Marking Experiments in Private Streams of Michigan

Data from two privately controlled streams are presented briefly since on these streams the fishing pressure is not as heavy as on public waters and records of the catch covered entire streams. The data on recoveries of tagged trout planted in two private streams parallel closely those from public waters except that the percentage of recovery was not as high, probably because of lower angling intensity.

Salmon Trout River.—In 1938, Mr. Lloyd L. Smith, Jr., then a graduate student at the University of Michigan, was engaged to make a general survey of the sport fisheries of the Huron Mountain Club. As a part of his researches, Mr. Smith marked legal-sized hatchery brook trout with jaw-tags before release in the Salmon Trout River, which flows into Lake Superior. The reader is referred to Mr. Smith's results, which are similar to those obtained in public trout waters of Michigan. A complete report of his work is to be found elsewhere in Volume 70 of the *Transactions of the American Fisheries Society.*

Kinne Creek.—Since 1938, members of the Institute staff have been furnished experimental facilities by the Wingleton Club, and the club members have cooperated by reporting their catches in considerable detail. On April 12-13, 1938, 1,500 brook trout purchased by the club from a private hatchery were jaw-tagged and released by the senior author. The average size of these trout was 7.25 inches (total length); 847 were of legal size (7 inches or larger) while 653 were from 6 to 7 inches long.

A total of 343 brook trout was taken in the 1938 season, of which 180 (52.5 per cent) were tagged fish. Although the 180 fish represented a relatively high percentage of the total brook trout catch, the recovery percentage was only 12 per cent. However, in this stream the brook trout population was relatively low. During the 1939 season, not a single tagged trout of the 1938 planting was recovered in a total catch of 92 brook trout. Some of the marked brook trout could have escaped into the Pere Marquette River through the rotary screens, but if any large number had escaped alive, some reports of tagged fish would have been received from the anglers on that stream. Since the findings on Kinne Creek agree with results from other experiments, the only logical conclusion is that there was an extremely heavy over-the-winter mortality. On April 11-12, 1939, legal-sized brown trout (994 in number) were marked with jaw-tags and released in Kinne Creek. A mortality of unknown extent occurred among the fish of this planting; more than 63 of the marked fish are known to have died. Numbers of the known dead were crushed to death between the rotary screens and the sill boards of the lower dam, and a few were picked up just above the lower dam. Nine records of recoveries sent in by anglers from the Pere Marquette River proved definitely that an unknown percentage of brown trout from this planting was able to survive passage through the screens.

From this planting, 98 tagged fish (10.2 per cent) were taken by Wingleton Club fishermen from Kinne Creek in the 1939 trout season. The tagged brown trout comprised 35.1 per cent of the total catch of legal-sized brown trout for the season. During the 1940 trout season, 10 tagged brown trout from the planting of April, 1939, were reported taken by the club members.

Failure of Marked Legal-Sized Trout to Survive from One Season to Another when Planted in Streams

In Kinne Creek, Canada Creek, and the Salmon Trout River there have been no recoveries reported of marked legal-sized brook trout planted in previous open seasons. In the North Branch of the Au Sable River, one report has been received of a tagged brook trout surviving to the 1940 season from the spring planting of 1939.

In the Pigeon River, no marked rainbow trout were reported in 1938 or in 1939 from the release of August, 1937, nor have any recoveries been reported during the current season (1940) from the 1938 fall or 1939 summer plantings of brown trout or rainbow trout, or the 1939 spring planting of brown trout. One recovery in 1940 from the April 1, 1939, release of tagged rainbow trout has been reported. This fish had migrated 260 miles to a point 17 miles off Sarnia, Ontario.

However, a very small percentage of "carry-over" from one season to the next was observed on both brook trout and rainbow trout from the plantings made in the Pine River. During the 1938 season, four

marked brook trout and five marked rainbow trout were recovered from plantings made during the summer of 1937. In 1939, 18 tagged trout were recovered from releases made in previous years; 17 (15 rainbow trout, 2 brook trout) were from plantings made during 1938, and one brook trout came from the July planting of 1937. There is evidence that a very small percentage of brown trout may survive from one season to the next. From 500 tagged brown trout released in the Little Manistee River in June and July, 1939, two reports of recoveries have been mailed in by anglers to date (July, 1940) from 1940 angling. Catch records from the Wingleton Club show a total of 10 tagged brown trout recovered during the 1940 season to date from a planting of 994 fish in April, 1939. However, we have received no reports in 1940 from the Pigeon River, where tagged brown trout were released in April, June and July of 1939.

We have obtained no evidence that any marked trout planted in the fall survived more than one winter, and very few marked trout planted in the spring survived to the second season. The greatest numbers of fish recovered after two winters came from plantings made during the summer months.

Season-to-season survival, on the basis of the data now at hand, appears to be best in rainbow trout, next best in brown trout, and poorest in brook trout.

Results of Marking Experiments in Michigan Lakes

It has been pointed out in the preceding pages that yearling trout do not overwinter successfully when planted in streams. However, when fall plantings of adult rainbow trout were made in several trout lakes of the Pigeon River Forest, generally good results were obtained (the results of the earlier experiments on these lakes were reported by Eschmeyer, 1938). These lakes which are of the "pot-hole" type vary in size from 5 to 40 acres. They have neither inlets nor outlets; hence spawning facilities are lacking and fishing must be maintained by the introduction of hatchery trout. Data on returns from the lakes show recovery percentages (obtained by creel census) on these waters as high as 66 per cent in the season following planting (Table 9). These results are in direct contrast to those obtained from fall plantings of legal-sized rainbow trout in the streams, where 1.2 per cent represented the maximum recovery by anglers in the following year (Tables 2 and 3).

Table 9.—Results of fall stocking of adult rainbow trout in certain Michigan lakes as determined from creel censuses and marking experiments

Lake	Date stocked	Number stocked	Number recovered	Percentage recovered	Year recovered
South Twin	1935	100	64	64.0	1936
North Twin	1937	100	66	66.0	1938
Pickerel	1939	400	93	23.3	1940
Hemlock	1939	303	113	37.3	1940
Burt	1939	500	69	13.8	1940

In South Twin Lake no rainbow trout were present before the planting of 100 adults in the fall of 1935. During the 1936 trout season, creel-census clerks recorded 62 of these fish, and 2 were later taken in nets by an Institute survey party. No fish were planted in 1936, but in 1937, 9 of the 36 fish theoretically remaining were recorded in the creel census. Thus the total known return to the anglers was 73 per cent of the original planting.

Similar results occurred after the introduction of 100 marked adult rainbow trout in North Twin Lake in the fall of 1937. The 1938 creel census for this lake showed that 66 of these fish were taken by anglers.

Pickerel Lake was stocked with 400 fin-clipped adult rainbow trout in the fall of 1939. Creel-census records for the period, April 27 to May 5, 1940, listed 93 marked trout recovered (23 per cent of the original planting and 83 per cent of the total catch of 112 rainbow trout). Since May 6 there have been unverified reports that at least 20 other marked rainbow trout have been captured in Pickerel Lake.

In Hemlock Lake 303 fin-clipped rainbow trout were available for the 1940 season from introductions made in July and October, 1939. The creel-census clerks recorded 113 marked rainbow trout (the entire catch) during the first 9 days of the season, a known return of at least 37 per cent from these plantings.

Interesting results are appearing from a planting of tagged yearling rainbow trout made in September, 1939, in Burt Lake (area 27.3 square miles). Of 500 tagged fish, 69 (13.8 per cent) have been taken to date (December, 1940). They have been recaptured in every stream tributary to or distributary from Burt Lake. The growth of these fish over the winter and through spring and summer ranged from one-quarter inch to 7 inches.

It is emphasized that the returns from this planting in Burt Lake were obtained through the cooperation of the anglers and through the cooperation of attendants at the Wolverine Rearing Station on the Sturgeon River. Newspaper publicity, and stream-side posters called attention to the release.

The results from experimental releases of marked adult rainbow trout during the open season in lakes of the Pigeon River Forest demonstrate that the anglers will remove about the same percentage, or possibly more, as when similar plantings are made during the open season in streams. Two hundred fin-clipped rainbow trout were planted in July, 1939, in Hemlock Lake, and before the season closed, 97 were captured by anglers—a recovery of 48 per cent. A planting of 300 marked rainbow trout in North and South Twin Lakes at the same time was a failure by comparison, as only 5 fish were retaken during the 1939 season, and only three fish of this same release were recorded in the first nine days of 1940.

Obviously th entire catch of the angler in these small lakes is of hatchery origin. As on the streams, a very large percentage of the

total catch is removed by a small percentage of anglers. Fishing on these lakes is best in May and June (well before many tourists have arrived) and sometimes is good in late August also. The local anglers take more than their share of the trout from these lakes before the surface waters are too warm, and almost never visit the lakes during the months of July and August, while the tourist fishes vainly for his trout. Because of the small size of these lakes, plantings can be made from the most convenient point on the shoreline with the assurance that the trout will distribute themselves in the lake.

Possible Sources of Error in the Data

Loss of tags.—At the end of the 1938 season we were not certain that our results concerning the relative merits of spring and fall planting of legal-sized trout were correct, because a control experiment indicated a great loss of tags from fish released in the fall of 1937. Another control experiment, in which Monel-metal tags from two companies were used, was established at the Grayling Hatchery on October 21, 1938 (Table 10). Brook trout, brown trout, and rainbow trout, all 7 inches long or larger, were used. The experimental fish were examined on July 7, 1939, and on April 18, 1940.

There has been no evidence of losses of tags from either brook trout or brown trout, but the rainbow trout at the last examination showed losses of tags, caused by jaw growth, to the extent of 8 per cent of the original number tagged. It may be concluded safely that the tags were of the proper material and construction to stay in place on all species of trout at least over one winter after tagging. Parallel results from spring and fall plantings of fin-clipped trout verify the conclusion.

Mortality due to marking (tagging or fin-clipping).—The control experiment described above indicates also that there may be a somewhat higher mortality in both tagged and fin-clipped brook trout than in the normal fish. However, the extent of the mortality among the experimental trout is uncertain. The figures presented in Table 9 are probably too high, because of the known escape of marked experimental fish from the holding pond. One of the tagged experimental rainbow trout was recovered from the East Branch of the Au Sable River above the Grayling Hatchery. To date, the mortality on the tagged brown trout and rainbow trout has been less than on the untagged control fish of the same species.

The fins removed on the fin-clipped brook trout have regenerated either very little or not at all; in no instance would a fish so marked be unrecognizable to a trained census clerk inspecting a creel.

Mass migration of the planted fish, or a poor creel census.—In the course of the last three years, streams and lakes where tagged fish were released have been well posted with signs requesting reports of recaptures. The digest of the fishing laws distributed to all who pur-

Table 10.—Control experiment on marked trout of legal size, initiated October 21, 1938, at Grayling Hatchery

[Total lengths are given in millimeters]

Date of examination	Item	Brook trout				Brown trout		Rainbow trout	
		Unmarked	Tagged (Tag No. 1)	Tagged (Tag No. 2)	Fin-clipped	Unmarked	Tagged	Unmarked	Tagged
Oct. 21, 1938	Number of fish	100	50	50	50	50	50	50	50
	Average total length	187	190	193	186	190	197	201	195
July 7, 1939	Number of fish	99	37	35	28	37	41	45	47
	Average total length	231	244	244	248	248	247	270	256
Apr. 18, 1940	Number of fish	82	35	32	28	36	41	45	49
	Average total length	283	290	292	299	285	281	331	307
Apr. 18, 1940	Average increase in length to date	96	100	99	113	95	84	130	112
	Percentage surviving to date	82	70	64	56	72	82	90	98
	Percentage observed to die at hatchery	9	15		0	0	0	0	0
	Percentage of unobserved mortality or escapement	9	18		44	28	18	10	2

chase licenses calls attention to the presence of marked fish and requests reports of capture. Local and metropolitan newspapers have carried accounts of marking experiments and pictures of tagged or fin-clipped fish. If any large proportion of tagged trout moved out of the census area, a number of returns would have been reported by mail. Each succeeding year during the census we received fewer returns from the Pine River by mail; only five marked trout were reported in this manner from the Pine River in 1939. This small number of returns indicates also that the creel-census crew was performing its work efficiently in the census area. The crew on the North Branch of the Au Sable River had a similar record.

The road pattern in the vicinity of the Pigeon and Little Manistee Rivers interfered with the efficiency of the creel censuses on those waters. Returns by mail were more numerous and incidentally were of great value, particularly from the Pigeon River, where it was found that there was a fairly large downstream movement of the rainbow trout planted in the spring.

The scarcity of returns outside of the census areas as contrasted with 69 voluntary reports from the Burt Lake planting (page 462), where no creel census was conducted and where reports from anglers furnished the only records, indicates further that there was no extensive migration outside the census areas and that the crews on the Pine River and the North Branch of the Au Sable were reasonably efficient.

Acknowledgments

The authors wish to express their appreciation once again to the Michigan Conservation Commission for the opportunity to continue this investigation. The following hatchery supervisors and their staffs have made the experimental plantings and have otherwise assisted in the experiments: Robert Fortney, Paris, Michigan; Hans Peterson, Grayling, Michigan; Arvin Walcott (deceased), Harrietta, Michigan; James Wilkinson, Oden, Michigan; Guy Lincoln, formerly supervisor at Oden, Michigan.

The Michigan State C.C.C. and the U. S. Forest Service furnished enrollees for creel-census work on five streams.

Summary

1. Comparable plantings (equal numbers of fish released at the same time of year) of legal-sized brook trout and rainbow trout yield approximately equal returns to the angler's creel. A smaller return to the angler of brown trout is indicated by limited data for that species.

2. Fall planting of all species of trout in streams has been found to be inefficient. For brook trout, returns from early spring introductions were six times greater than those from fall plantings; for rainbow trout 32 times greater; and for brown trout twice as great. That survival is low over the winter seems to be established definitely by all experiments that have been conducted in trout streams. Plantings approximately a month prior to the open season yielded about the same

returns as plantings made during the fishing season for brook trout and rainbow trout but were not as efficient for brown trout.

3. Smaller plantings (from 100 to 160 adult trout per mile of stream averaging 50 feet in width) resulted in higher recovery percentages for brook trout and rainbow trout than did larger plantings. A greater percentage of anglers benefited over a longer period of time from smaller releases, migration appeared to be less extensive, and the depletion of the stock of native fish was lessened or avoided. Similar comparative data are not available for brown trout.

4. No significant difference in the percentage caught, duration of the effects of plantings, or in the number of fishermen benefited was found between "spot" or "boat" plantings during 1938 when smaller plantings were made.

5. In general, the effect upon the total catch and the quality of the fishing (catch per hour per angler) was inversely proportional to the density of the native population of the species planted and to some extent directly proportional to the number of fish in the planting.

6. The percentage of anglers benefiting from the stocking of legal-sized trout was extremely low (from 5.7 to 20.6, average 11.8) in spite of plantings that were considered generous. In northern Michigan streams it seems evident that chief reliance must be placed upon the native stock to yield the bulk of the anglers' catch. Doubtless this conclusion would not hold on southern streams where the fishing pressure is heavier and ecological conditions are generally less suitable for trout.

7. Marked rainbow trout and brown trout contributed to the catch for at least 8 weeks after release, whereas brook trout were caught out usually within 4 weeks. The majority of all planted fish taken was caught by the end of 4 weeks. The marked fish surviving from one season to the next constituted an insignificant percentage of the total catch.

8. Results from marking experiments on private streams were of a similar nature to those obtained on public trout streams, except that recovery percentages were not as high as on public streams, probably because of lower fishing intensity.

9. Adult rainbow trout can be released in the fall in trout lakes at the rate of between 30 to 50 fish per acre of lake surface with the expectation that at least from 50 to 70 per cent will be taken during the following season.

10. A control experiment conducted in hatchery ponds proved that there has been no loss of tags from brook trout and brown trout, but that 8 per cent of the rainbow trout had lost their tags during the second winter. Such mortality as has occurred would not affect the validity of the conclusions presented here for fish released in natural waters. Publicity through newspapers, fishing law digests, and stream-side posters have aided in obtaining returns outside creel-census areas, and returns by mail have yielded no evidence of mass migration. The relative scarcity of returns by mail for fish taken in the census areas indicates also fairly efficient coverage of the fishing by the creel censuses.

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Discussion

Dr. A. G. Huntsman: Have you come to any conclusions with regard to the reasons for the ineffectiveness of fall planting?

Dr. Shetter: I can offer only certain suppositions. Winter conditions are very hard on trout, and I do not know that they are as hard in Michigan as they are in communities farther north. There is, however, one bit of evidence that I might cite. In the fall of 1938 we planted in the Pine River some of the nicest brook trout it was ever my privilege to handle. The average length was about 11½ inches and the weight three-quarters of a pound. During that winter we had three letters from one of the owners of a private club on the Pine River whose caretaker had been instructed to shoot mergansers, and three tags from these fish, all 11 inches or larger, were found in the stomachs of the mergansers. I won't say that this circumstance occurs in every brook trout stream in Michigan, but it indicates that at certain times the mergansers can be a problem.

Our streams sometimes are heavily flooded in the spring, scoured by ice—normal ice and anchor ice too. But just why fall planting of adult fish is not successful I should hesitate to say.

Mr. C. R. Lucas: Have you ever tagged native fish to find out how they winter as compared with hatchery fish?

Dr. Shetter: I did originally on the North Branch of the Au Sable River, but results were not comparable because I tagged all sizes. We may eventually be able to answer that question for brook trout at our Hunt Creek experimental station. As soon as we have a weir installed it will be possible to enter upon a large-scale program of marking native and hatchery fish.

Dr. V. D. Vladykov: What was the longest period that elapsed between the date of tagging brook trout and the date of recovery?

Dr. Shetter: One fish was captured in 1939 which was planted in July, 1937. Very few fish carry over from one season to the next.

Dr. Vladykov: Do you find that the brook trout carry their tags well?

Dr. Shetter: We find that the brook trout carry the tag well, but for some reason the mortality in the marked brook trout was higher than in the other two species. Why, I do not know.

Dr. Vladykov: Did you notice that the brook trout which have been tagged have a tendency to return to the same place, sometimes the same spawning ground, even the same feeding ground?

DR. SHETTER: Yes, that was true. On the North Branch of the Au Sable River they returned every summer almost to the same hole.

DR. VLADYKOV: Brook trout tagged in the Laurentides Park in Quebec on several occasions were recaptured exactly at the same spot where they were tagged the previous year.

Is it possible that the tagged fish taken by the merganser were weak or even dead, having become tangled or caught between algae or roots of plants?

DR. SHETTER: There have been very few instances where we knew definitely that tagged fish were caught on brush or grass. Whether by chance or not, we have heard of no more than five instances in 15 to 20 thousand fish marked and planted where that has occurred. My observations lead me to believe that mergansers take live rather than dead fish.

MR. L. S. ROACH: In almost every instance where nets are operated in lakes or streams there is supposed to be a much better anglers' catch immediately after their operation. It is contended by the fishermen that there has been an increase in the catch of native fish during and after the operation of these nets. Have you any explanation for an increase in the catch of native fish as compared to the catch of introduced fish?

DR. SHETTER: I do not know whether the operation of a net would have any effect or not. But there is a possible stimulation—and this is entirely supposition. After the fish have had their fins clipped certain species tended to move around a little more; they were irritated, so to speak, by the removal of the fin.

THE EFFECTS OF HIGH VACUUM ON FISH

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ABSTRACT

A set of three large siphon tubes has been installed on the lower St. Francis River in Arkansas, which pass the normal flow of the river. They operate with a negative pressure equivalent to from 18 to 26 inches of mercury. Experiments with fish held under negative pressure in aquaria for the length of time required to pass through the tubes have been conducted and some species of fish show serious injury. Those that are physostomous are more able to make the sudden change or adjustment in the swim bladder necessary when passing through the tubes, while physoclistous fish are unable to make the sudden adjustment and suffer hemorrhage in the circulatory system and many die. There is need for close cooperation between engineers and fishery administrators in designing and constructing devices that are apt to affect fish life in public waters.

INTRODUCTION

After finding dead and disabled fish in the St. Francis River below the Marked Tree Siphons a study was undertaken to determine the effects of vacuum on fish life. These siphons, about 200 feet long and 9 feet in diameter, are used to lift water from the St. Francis River over a levee and into the river bed on the outside of the floodway. The operating range of the siphons fluctuates from a minimum of about 18 inches of vacuum to a maximum of about 26 inches.

Disabled fish found in the stream below the siphons showed signs of a possible hemorrhage or injury to the swim bladder caused by the vacuum. Some few individuals had vomited the stomach contents and the everted esophagus was drawn up into the throat. A majority of the dead fish were crappies (*Pomoxis* sp.) along with a few largemouth black bass (*Micropterus salmoides*) and wall-eyed pike (*Stizostedion v. vitreum*). Later reports also included the gizzard-shad (*Dorosoma cepedianum*) and drum (*Aplodinotus grunniens*) among the fish that were killed.

DESCRIPTION OF VACCUUM AQUARIUM

In order to duplicate the condition of vacuum in the siphons and to determine its effects, a small aquarium was built with heavy plate glass sides outside of a metal frame. The glass was cemented to the metal frames and held in place with wooden strips. The top was drilled for stud bolts and an air-tight lid fitted. The outlet pipe was fitted with an automobile tire valve stem to withhold the pressure from the outside as the air was removed from the aquarium. A small brass cock was screwed into the outlet as a release. Some difficulty

was encountered in making the aquarium absolutely air-tight, but after the large air leaks were stopped, a small stream of water poured over the aquarium during tests provided a water seal which made the tank tight.

Experiments and Results

The vacuum aquarium was connected with a short rubber hose to a pipe line in the operating room of the siphons and the vacuum for the aquarium was provided by was one of the tubes that was in actual operation. The gauge indicated that the siphon was operating at a vacuum pressure of between 24 and 25 inches of mercury. The following paragraphs constitute a brief report on the tests run and the results obtained.

Experiment 1.—Six bluegill bream (*Lepomis macrochirus*) about 4 inches long were held at the peak for 15 seconds, allowing 15 seconds for the vacuum to build up and 15 seconds for the release; making a duration of 45 seconds from start to finish. At the peak the fish were drawn to the surface of the aquarium, and lay on their sides struggling to retain balance with their eyes bulging from the sockets about a quarter of an inch. As the vacuum was released the fish sank to the bottom of the aquarium. Two were killed and the remaining four exhibited physical distress as a result of the test. These four regained their equilibrium and apparently were in good condition 24 hours later.

Experiment 2.—Four adult bluegill bream were held in a vacuum of from 0 to 25 inches of mercury for 10 seconds and then released with no permanent serious effects. The fish lost their balance when under vacuum and were drawn toward the surface as the vacuum pressure increased but quickly returned to the bottom when the vacuum was released. The fish regained their balance when the pressure returned to normal.

The same bluegill bream were then held at the maximum of 25 inches for 25 seconds. At the end of the test one fish was on its side with eyes protruding from the sockets, dying and the other three were visibly affected but seemed to be reviving from the shock. About 30 minutes later two bream were dead and two were alive. The two live fish appeared to be in good condition 24 hours after the test.

Experiment 3.—Twenty golden shiner yearlings (*Notemigonus crysoleucas*) were placed in the aquarium and were subjected to the maximum vacuum pressure of 25 inches of mercury for 30 seconds. The fish were drawn toward the surface under vacuum and settled to the bottom when released. All regained their balance and 24 hours later all were alive and in good condition.

Experiment 4.—Ten adult golden shiners were subjected to two exposures to a vacuum pressure of 25 inches for 30 seconds at each exposure. These minnows retained their balance and were active near the middle and bottom of the aquaria during the tests. Although

they were uneasy during the test and after, but none was killed and all were normal 24 hours later.

Experiment 5.—Four crappies (*Pomoxis* sp.) about 4 inches long were subjected to a vacuum of from 15 to 18 inches of mercury for 55 seconds. This exposure was considered to be about the minimum for successful operation of the siphon and the maximum length of time required for a fish to pass through. The crappies manifested uneasiness as soon as the vacuum was applied, and before the test was completed rose to the surface on their sides, with the eyes bulging from the sockets. After 12 and 18 seconds, respectively, two fish, after rising to the surface had settled to the bottom of the aquarium. This might indicate that the swim bladders, after expanding to the maximum had burst, allowing the fish to settle to the bottom. One minute after the vacuum was released all the fish were on the bottom in a dying condition and in 1½ hours all four were dead.

Experiment 6.—Two adult crappies weighing about 12 ounces each were subjected to a vacuum of 25 inches for 30 seconds. The fish showed signs of uneasiness as soon as the vacuum was applied. Blood was drawn toward the surface of the body around the vent within 20 seconds and was visible at small abrasions on the body. At the end of the test both fish sank to the bottom of the aquarium completely stunned. Milt was drawn from the male and eggs from the female during the test. Fifteen minutes after completion of the test both fish were on their sides apparently dying. One revived, however, and was alive 24 hours later but had not regained complete control of its balance.

Experiment 7.—Five largemouth black bass (*Micropterus salmoides*) 7 inches long were subjected to a vacuum of 25 inches for 15 seconds. The fish were drawn to the surface with their eyes bulged and struggling, during the test. All sank to the bottom when the vacuum was released; four maintained their equilibrium and one died. Four minutes later another was dying. Fifteen minutes after the test was completed two fish were dead and 30 minutes after the test two more fish were dead. Twenty-four hours later the sole remaining fish was alive and appeared to be in good condition. Four out of the initial five fish were killed in the experiment.

Experiment 8.—Two largemouth black bass weighing about 12 ounces each were subjected to the maximum vacuum of 25 inches for 22 seconds. Their eyes bulged but they retained their balance fairly well. This pressure and length of exposure sufficient to have passed the fish through the siphon. A second test of 20 inches for 4 seconds completely immobilized both fish. The fish were listless when removed from the aquarium and both died in a half hour.

Experiment 9.—Two adult largemouth black bass each weighing about 3 pounds were subjected to a vacuum of 25 inches for 30 seconds. Both fish showed signs of distress as soon as the vacuum was applied. At 15 inches both floated on their sides to the surface,

struggling and with eyes bulging. One fish regurgitated apartly digested minnow and eggs were extruded from the other during the test. At the termination of the test both fish were lying listlessly on their sides. Twenty-four hours later one fish was alive and apparently in good condition and the other was dead.

Experiment 10.—Two yearling carp (*Cyprinus carpio*) about 8 and 10 inches long were subjected to a maximum of 25 inches for 30 seconds. The larger fish did not lose balance during the test and remained struggling in the middle of the aquarium. The smaller fish lost its balance and was drawn to the surface for a few seconds but regained balance as soon as the vacuum was released. Both were alive and active at the end of the test and also 24 hours later.

Experiment 11.—Four bullhead catfish (*Ameiurus* sp.) ranging in weight from 4 to 16 ounces were subjected to the maximum vacuum of 25 inches for 25 second with no apparent serious effects. The fish remained on the bottom of the aquarium during the test and all were alive and active 24 hours later.

Experiment 12.—A long-nosed gar (*Lepisosteus osseus*) 11½ inches long was placed in an aquarium at a vacuum of 25 inches of mercury for 45 seconds.[1] As the vacuum was increased from normal pressure the fish began to rise to the surface and release air from the swim bladder. When the vacuum was released the fish sank to the bottom and rose to the surface in 3 minutes to take on another supply of air. After the fish had been allowed 8 minutes to refill the swim bladder another test was started. Five seconds after the vacuum was produced the fish began belching air and apparently had exhausted the supply when the maximum vacuum of 27 inches was reached after an interval of 25 seconds. The vacuum was held at the maximum for 45 seconds and then released. The fish regained balance 10 seconds after the pressure returned to normal, and showed no ill effects 24 hours after the experiment.

Discussion[2]

The vacuum used in the tests (except for Experiment 12) was the same as in the river siphon; the aquarium being connected directly to an operating siphon during the tests. The length of the individual tests was thought to be about that required for a fish to pass through the tube. Since no accurate determination of the time required for an object to pass through the siphon could be made, the assumed maximum may be in error. It is possible that a fish may pass through a siphon in less than 30 seconds, however, from 20 to 30 seconds was considered sufficient.

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[1]Dr. Bertil G. Anderson conducted this experiment at the Franz Theodore Stone Laboratory, Put-in-Bay, Ohio (unpublished).

[2]Joseph C. Jenkins in an unpublished report on "The Effect of Negative Pressure on Fish," obtained results comparable to those in our experiments. The work was done at the Franz Theodore Stone Laboratory of Ohio State University in 1939.

There is considerable turbulance and surging of the water in the siphon tubes, and therefore a possibility that fish could suffer mechanical injury in passing through the siphons but at the present time it is thought that the vacuum alone is responsible for the serious damage. The game fish were affected more seriously than the rough fish and minnows tested. The crappies were least able to withstand the vacuum, with largemouth black bass and bluegill bream next in respective order. Little or no damage was suffered by carp, bullhead catfish, minnows and long-nosed gars. This observation might indicate that fish having a duct leading from the swim bladder to the alimentary tract are capable of releasing the air quickly under vacuum, and fish lacking the duct are unable to compensate for the quick change and suffer a ruptured swim bladder and hemorrhage. Minnows and long-nosed gar in particular were observed to belch air as the vacuum was applied.

Further experimentation should be conducted on the species of fish native to the part of the St. Francis River where the siphons are located. If possible, some means should be devised to prevent fish from entering the siphons and being killed. Either the negative pressure or vacuum should be changed or regulated to be within the limits the game fish can withstand, or the fish should be prevented from being drawn into the siphons by an electric fish screen or stationary bar screens. No definite solution to the problem can be recommended. Electric fish screens are recommended for shunting fish away from side outlets, thus keeping them in the main stream. Normally the main stream flow passes through the siphon tubes. The crappie, for instance, are not capable of fighting strong currents and when caught in the swift water at the inlet bells would pass through an electric screen and on through the tubes. If permanent racks were installed the fish might become exhausted fighting the current and perish against the racks. There is also the problem of keeping racks clean as many tons of drift timber come down at flood seasons.

After being started the siphons build up vacuum until a certain maximum negative pressure point is reached. If it is found that the siphons do not kill fish at low vacuum pressures a release valve could be placed in the top of each tube, so regulated as to prevent the gradual increase in vacuum pressure. There is doubt that the siphons will operate at a negative pressure low enough to allow fish to pass through without injury. The fluctuation in water level in the river is the primary factor influencing the vacuum pressure at which the siphons operate.

Conclusion

The siphons are doing serious damage to certain species of game fish in the river. Further experiments on all species of fish should be made before recommendations for correcting the situation can be made.

It would be well to include in these experiments the aquatic organisms that are essential for sustaining fish life.

Floods are a serious menace to the welfare of the people in this section of the state and the siphons were designed and built to meet an unusual local soil condition. There is need for closer cooperation between engineers and fishery administrators in designing and constructing structures that are apt to affect fish life in public waters.

Had a series of experiments been completed before these siphons were built, engineers would have had an opportunity to design and build structures that would be compatible with fish life.

SEXUAL DEVELOPMENT OF THE CROAKER, *MICROPOGON UNDULATUS*, AND DISTRIBUTION OF THE EARLY STAGES IN CHESAPEAKE BAY[1]

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ABSTRACT

Croakers of varying ages and with approximately an equal distribution of the sexes were studied to determine gonad development. Data gathered indicate that males mature earlier than females. The smallest male to reach sexual maturity was 24 centimeters long, whereas smallest ripe female was 27.5 centimeters long, total length. The ages of these fish, as indicated by scale examinations, were 2 and 3 years, respectively. All fish 3 years or older had ripening gonads. The fish studied were collected by random sampling, in which the ratio of males to females in the areas changed from 50:50 in June to a ratio of approximately 35:65 during early August. This evidence, further supported by records of ocean catches, indicates that males begin their spawning migrations out of the bay earlier than females. At the time of departure whether males or females, the gonads have reached comparatively complete maturity. Evidence based upon tagging, gonad development, and samples from commercial catches, shows that sexually mature croakers leave bay waters largely during the month of August, and that virtually all fish have departed by September 15, the greatest wave of migration taking place during the first week in August. Sexually mature croakers return to the Chesapeake Bay waters during late spring.

During the winters of 1938, 1939 and 1940, larval stages of the croaker were taken within the Bay. It was possible, through the use of a specially constructed otter trawl, to gather materials which provided information on growth and up-bay distribution of very young stages. The presence of larval croakers well up in the bay can be explained by currents which carried the young fish up the bay from the oceanic spawning areas.

INTRODUCTION AND METHOD OF SAMPLING

A study of the biology of the croaker, *Micropogon undulatus* (Linnaeus), was initiated at the Chesapeake Biological Laboratory in 1938. A part of this research, that dealing with sexual maturity, spawning migrations, and the distribution and growth of the young fish is reported here.

Random and selected samples of croakers were obtained from various sources at different times during the years 1938, 1939 and 1940. In the fall, winter and early spring of these years, collections were made aboard commercial trawlers that operated on the ocean. These fish were measured, scale samples removed and gonads examined. The gonads were classified according to a numerical system (Table 1). At the same time surface and bottom temperatures were taken and plankton net samples were obtained. From the middle of April to the last of September, when the fish were in the bays and rivers, samples were available from pound nets, haul seines, and hook-and-line fishermen.

[1]Contribution No. 39 from the Chesapeake Biological Laboratory.

Table 1.—Field classification of stages of sexual development in the croaker

Stage	Description of the gonads	
	Female	Male
Immature	Ovaries transparent yellow, rather round but thin; eggs undeveloped.	Testis a long thin strand with no signs of development; very flat, grayish in color.
I	Ovaries small and hard to the touch; pale yellow, eggs not distinguishable with the naked eye.	Testis narrow, almost triangular, and hard to the touch; grayish.
II	Ovaries about 1/3 larger than I; eggs more advanced and visible through membrane; few faint blood vessels seen on walls; brighter yellow.	Testis about 2 times as large as I, yellow gray in color.
III	Ovaries about 3/4 full size; eggs clearly seen through the ovary membrane; bright yellow with numerous blood vessels.	Testis much wider and thicker, and greasy in appearance, with several longitudinal striations; whiter and softer than previous stage.
IV	Ovaries swollen until nearly fill the body cavity. Yellow-rose, with blood vessels almost gone; eggs loosely attached.	Testis very wide and soft; striations have been filled out and have disappeared; milt can be obtained along with blood by pressing the sides of the fish.
V	Actual spawning with the eggs running freely from the fish.	Actual spawning; testis white and fully developed; milt running at the slightest pressure.
VI	Spent; ovary flabby and about ½ the size of Stage I; bloody with few eggs clinging to the membrane.	Spent; testis still white but the upper part is very thin, narrow and gray.
VII	Ovary partly recovered; starting to assume the condition of Stage I.	Testis much harder, thinner, and grayish, and aproaches Stage I in appearance.

Larval and post-larval specimens were collected from the bay in the winter and early spring by means of a specially constructed 30-foot otter trawl with a quarter-inch bunt. This net was towed for a 20-minute period at various stations in Chesapeake Bay (Figure 1). Along with this net a bottom dredge with a fine-meshed bag was towed to secure larval stages, while 10-minute plankton tows were made at the surface and bottom for eggs and early larvae. Temperatures and water samples from both the surface and bottom were taken. The water was analyzed later for salinity by Mohr's procedure of determining chlorides. The larval and early post-larval forms were measured from the tip of the snout to the end of the vertebral column (standard lengths).

Age at Maturity

Different authors in several localities have reported differences in the age at which croakers spawn. Welch and Breder (1923) studying Atlantic Coast croakers wrote that "maturity is reached at the age of three or four years," while Pearson (1929) concluded that the croakers of Texas spawn at the end of the second year. Examination of almost 1,000 gonads of croakers of various ages, from both the bay and the ocean, has revealed that only about 45 per cent of the males reach maturity at the end of the second year, and that no females at this age gave indications of ripening. The smallest mature male, taken late in August, was 24 centimeters long and 2 years old. The testes of all males in their third year or older had begun to develop for spawning in the fall. No female fish had reached sexual maturity in the sec-

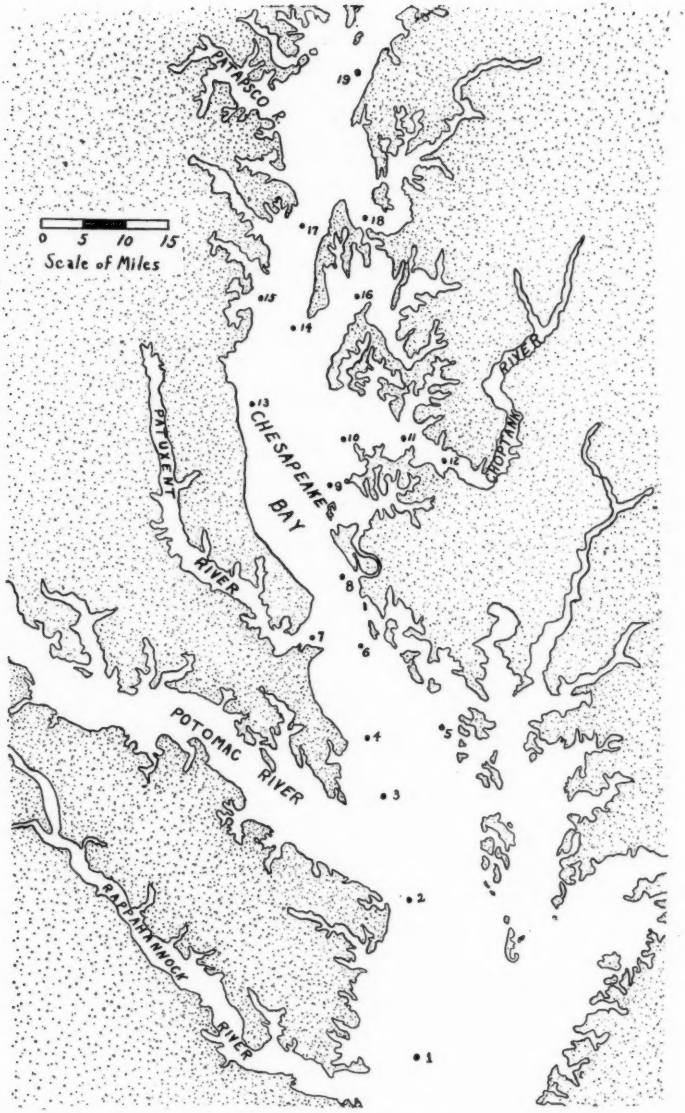

Figure 1.—Sketch map of a portion of Chesapeake Bay, indicating localities at which samples of croakers were obtained.

ond year, while all females regardless of size, matured sexually in their third year (Table 2). The smallest mature female observed was 27.5 centimeters. This data is not necessarily contradictory to Pearson's findings on croakers in Texas that the fish reach maturity at the end of the second year, since Chabanaud (1929) and Hildebrand and Cable (1930) suggested that individuals of the same species may mature at an earlier age in warmer climates.

Migrations and Sexual Development of Croakers

The croaker, like most other commercial fishes of the Middle Atlantic region, is strictly a summer visitor to inshore waters. With the approach of cold weather it migrates to warmer waters offshore, where in recent years it has supported an otter trawl fishery.

Croakers migrate in great numbers from the ocean into Chesapeake Bay in the spring. Hildebrand and Schroeder (1928) noted this seasonal movement, and a spring migration of croakers likewise was described by Gunther (1938) in Louisiana, and Pearson (1929) in Texas. In the spring when the croakers move into Chesapeake Bay, the sex distribution is about equal (Table 3). Once in the bay, the fish migrate to various sections, feed extensively and mature, or rebuild their gonads, throughout the summer. All mature fish examined in the spring had gonads in a resting stage (I). By early July the testes and ovaries of adult fish were in one of the first three stages of development, and by August, Stages II and IV were most frequently found. Ripening progressed during the late summer and fewer large fish were caught, which indicated that the large mature fish had begun to return to the ocean.

The immature fish remain in the bay until driven out by adverse temperatures. The mature fish begin to leave earlier, for, as ripening progresses during the late summer, fewer large fish are caught.

Table 2.—Relationship of the age of croakers to sexual maturity based on collections off Solomons, Maryland, in July and August of 1938, 1939, and 1940

Age in years	Percentage of Females in Maturity Stages					Total number of fish
	Immature	I	II	III	IV	
1 (0+)	100.0	0.0	0.0	0.0	0.0	94
2 (1+)	55.2	31.0	13.8	0.0	0.0	87
3 (2+)	0.0	29.2	56.2	6.3	8.3	96
4 (3+)	0.0	9.1	36.4	36.4	18.1	22
5 (4+) or more	0.0	0.0	25.0	25.0	50.0	4
Total						303

Age in years	Percentage of Males in Maturity Stages					Total number of fish
	Immature	I	II	III	IV	
1 (0+)	100.0	0.0	0.0	0.0	0.0	112
2 (1+)	100.0	0.0	0.0	0.0	0.0	135
3 (2+)	0.0	70.4	22.3	7.3	0.0	108
4 (3+)	0.0	34.1	29.3	26.8	9.8	41
5 (4+) or more	0.0	17.4	39.1	34.8	8.7	23
Total						419

Table 3.—Sex ratio of mature croakers throughout the year

Locality	Date	Number		Total	Percentage	
		Males	Females		Males	Females
Solomons, Md.	May 17, 1939	52	51	103	50.5	49.5
Solomons, Md.	June 14, 1939	22	23	45	48.9	51.1
Solomons, Md.	July 27, 1938	38	60	98	38.8	61.2
Solomons, Md.	July 12, 1939	9	25	34	26.5	73.5
Solomons, Md.	July 22, 1940	32	24	56	57.1	42.9
Total	July	79	109	188	42.0	58.0
Solomons, Md.	Aug. 10, 1939	29	62	91	31.9	68.1
Solomons, Md.	Aug. 9, 1940	11	9	20	55.0	45.0
Total	August	40	71	111	36.0	64.0
Solomons, Md.	Sept. 14-15, 1938	18	40	58	31.0	69.0
Colonial Beach, Va.	Oct. 10, 1938	8	29	37	21.6	78.4
Atlantic Ocean, Whimble Shoals, N. C.	Nov. 29, 1938	55	45	100	55.0	45.0
Off Currituck Light, N. C.	Dec. 6,1939	49	51	100	49.0	51.0
Whimble Shoals, N. C.	March 3, 1939	47	53	100	47.0	53.0
Off Bodie Island, N. C.	April 3, 1940	70	74	144	48.6	51.4
Grand total		440	546	986	.....	.....

The seaward spawning migration extends over a long period of time, from July until November. The males tend to begin the journey before the females. Welch and Breder (1923) observed that males with running milt were taken in the ocean off Atlantic City, New Jersey, early in July, but no ripe females were recorded earlier than September. An average of all the examinations of total catches made in July reveal that 58 per cent of the fish present in the mid-bay region were females. During the first 2 weeks in August, the percentage of females increased to 64. By the last of August, most of the mature croakers had disappeared leaving the immature 2-year olds. The few remaining large fish were practically all ripening females.

Tagging experiments revealed that these immature croakers stayed locally until late in the fall, long after the mature fish had completed their spawning migrations. Tagging experiments also showed that once a mature fish began its migration toward the ocean, it lost little time en route to its destination. Ninety fish were tagged with disc tags, from the catch of a haul seine and released at the mouth of the Patuxent River on August 10, 1939. Twelve days later, one fish, a female, 29.5 centimeters long, was recaptured in a pound net near Wolf Trap, 75 miles from the point of release. Several other fish from this experiment were taken shortly thereafter between Wolf Trap and the ocean. The most rapid movement of a tagged fish was that of an individual marked on October 12 in the upper Potomac River and captured in the ocean near the mouth of the bay 7 days later.

Our observations suggest that most of the spawning is over by the end of November. In a sample of fish taken from the ocean on No-

vember 30, 1938, off Currituck Light, all 3-year olds either had gonads in a spent condition (Stage VI) or showing signs of recovery (Stage VII). Samples taken from the ocean in December, January and February showed continued recovery, with the ratio of males to females about equal (Table 3).

Distribution and Growth of Young Croakers

The very early developmental stages of the croaker have had little study, although several investigators, including Welsh and Breder (1923), Hildebrand and Cable (1930), and Gunther (1938), have reported incidentally of post-larval croakers at various points along the coast between New York and Texas.

Nineteen stations were established for sampling purposes at representative points on the bay between the mouth of the Rappahannock River and a point northeast of the mouth of the Patapsco River on the eastern shore (Figure 1). Depths at the stations ranged from the inter-tidal zone to 50 meters.

Plankton nets were towed periodically during the winter months of 1938-1939 at the 19 established stations and in many localities in shallow water. Similar tows were made but less regularly in the ocean between Currituck Sound and Cape Hatteras.

Although winter sampling was carried out for 2 years, no croaker eggs or larvae were found in the ocean, despite the fact that spawning occurs there. No eggs and few very small larvae were found in the bay. At the station nearest the ocean the larvae averaged 30.7 millimeters in length (Table 4).

In order to describe where croaker larvae were found in Chesapeake Bay, and to attempt to explain why they were found so far from their spawning grounds, it is advisable to describe briefly the bottom contour of this body of water. Chesapeake Bay is in the main,

Table 4.—Catch of larval and post-larval croakers by a special otter trawl during the winter and spring seasons of 1938, 1939 and 1940

Station No.	Number of hauls	Average catch per haul	Average length of fish (millimeters)
1	2	237	30.7
2	2	72	31.0
3	1	56	31.0
4	1	0	.....
5	1	0	.....
6	2	27	34.8
7	3	3	32.0
8	4	23	33.0
9	3	23	33.1
10	2	13	33.5
11	2	0	.....
12	4	0	.....
13	1	0	.....
14	5	3	37.8
15	1	0	.....
16	2	0	.....
17	2	0	.....
18	2	0	.....
19	1	0	.....

rather shallow, with an average depth of about 12 meters. A deep channel with frequent depressions to depths as great as 50 meters runs almost its entire length. This channel follows an irregular course, being on the east side in the upper and lower regions, and on the west side of the middle regions of the bay.

The young croakers that were taken in Chesapeake Bay were found only in waters 24 meters or deeper. The larvae taken at the stations nearest to the ocean were more abundant and smaller than those taken at any of the other stations. From these southern stations progressing northward in the bay, the number of post-larval fish diminished in numbers but gradually increased in size until Station 14, above Bloody Point, was reached. Beyond this station, no larval fish were found (Table 4).

The early larval stages taken at Station 14 on December 1, 1939, had developed so that they were no longer planktonic but free-swimming individuals. Up to this time their movement had been limited almost entirely to the action of currents. Station 14 was approximately 120 miles from the ocean. The presence of post-larval fish so far from their origin requires an explanation. The answer, at least in part, is found in the hydrographic investigations of Cowles (1930). His findings were duplicated by Newcombe, Horne and Shepherd (1939), and by observations made during the present study. Throughout the entire length of the bay runs a channel described previously. In this channel in the upper Chesapeake, salinities as high as 20.00 may be obtained in depths of 30 meters. For example, at Station 14, on February 1, 1939, the salinity at the bottom was 19.3 parts per thousand. Cowles offers the statement: "Current records show, at times, what appears to be a persistent tendency for the rather highly saline waters of the lower layers to move slowly into the bay." He observed the movements of this current in the deep water channels of both the middle and upper bay.

The location of the oceanic current and the presence of larval croakers coincide. No larval fish were taken at Stations 4, 5, 11, 12, 13 and 16, which although located in the mid-region of the bay, were in comparatively shallow water. At the same time as the sampling of these stations larval fish were found to be abundant in the deep and more saline waters of this same territory. Since larval croakers are present in the bay far from their origin, it is apparent that they are carried into and up Chesapeake Bay by currents of more saline water. The currents occur in the deep channel which extends nearly the entire length of Chesapeake Bay.

Summary

1. A segment of the male population matures at 2 years of age while all of the females fail to mature before their third year. The smallest ripening female was 27.5 centimeters.

2. All fish 3 years old or more show progressive ripening gonads throughout the summer and most are sexually mature by late August.

3. The males begin their spawning migration earlier than females. Almost all of the mature croakers migrate from the bay during August.

4. Larval croakers are found during the winter months in a deep channel running the entire length of the bay and only in that channel. The larval croakers at the mouth of the bay are much smaller, and more numerous than those found in the upper parts of the bay.

5. The small croakers are apparently carried into and up the bay by a current or currents of more saline water that occur in the deep channel which extends nearly the entire length of Chesapeake Bay.

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INSPECTION OF FISH BY THE STATE OF MINNESOTA

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ABSTRACT

The fish inspection system of the State of Minnesota was instituted in 1932 by the Department of Agriculture, Dairy and Food. It was created as a service to fishermen to determine if their catches were sufficiently free from parasitic infestation by the tapeworm *Triaenophorus robustus* to allow them to pass market inspection by the U. S. Food and Drug Administration. The service, which also regulates and certifies as to quality of fish, now covers all herring and tullibees produced for commerce by Minnesota fishermen.

A discovery by medical research scientists in the late 1920's led to the foundation of Minnesota's fish inspection system. These scientists, seeking to discover the source of the human tapeworm, *Diphyllobothrium latum*, were examining fish from the Great Lakes area that were utilized for human consumption. In the course of this work, they discovered extensive infestation of the fishes in the whitefish family (*Coregonidae*) by another parasite, *Triaenophorus robustus*, the tapeworm of the pike and pickerel family. An intensive survey by the Food and Drug Administration of the United States Department of Agriculture resulted, confirming the presence of this parasite. It was determined that lake herring, tullibee, and whitefish, important commercial members of the whitefish family, were all heavily parasitized in a number of Minnesota lakes. These lakes included Lake Superior, Lake of the Woods, Rainy Lake, and Lake Namakan, all of which support extensive commercial fisheries. The U. S. Food and Drug Administration immediately took steps to bar the interstate shipment of the parasitized fish.

Fishing and its allied industries furnish an important source of income to many residents of northern Minnesota. The lake herring catch of Lake Superior was annually about 4 million pounds and the International Lakes (Lake of the Woods, Rainy Lake, and Namakan Lake) ordinarily supplied about 2 million pounds of tullibees per year. The ban on interstate shipment of parasitized fish affected the major part of these catches, bringing severe hardship to many Minnesota families. The State of Minnesota took steps to find relief from the ensuing results. As a consequence, the writer began, in 1931, a study of the problem for the State Department of Agriculture, Dairy and Food.

An effort was immediately made to relieve the distress of the commercial fishermen and fish dealers along the north shore of Lake Superior and on the boundary lakes between Minnesota and Canada. These men were made familiar with the character of the ban parasitized fish and were taught how to detect the presence of the para-

sites in the fish. Such pioneering was difficult as the fishermen were not in sympathy with the ban. Parasitized fish had been known for years and so far as the fishermen knew no injury had resulted from eating them. They were informed that the U. S. Food and Drug Administration did not maintain that the parasite *Triaenophorus robustus* injures human health, but that action was instituted under the section of Federal law that defines a food article as adulterated if it is filthy or comes from the carcass of a diseased animal, which, of course, refers also to fish.

Extensive experiments and observations were then initiated to determine under what natural conditions, if any, lake herring and tullibees were produced that were sufficiently free from parasites to pass the interstate inspection. Thousands of herring were dissected and carefully examined for parasites. The findings revealed that infestation was not seasonal, the fish caught during the winter months showed practically the same degree of infestation as those obtained during the summer months. The extent to which the herring were parasitized was found to vary considerably—some lots showing infestation in as few as 15 per cent of the fish while other lots were as much as 80 per cent infested. The surveys conducted in 1931 and 1932 on tullibees of Lake of the Woods, Rainy Lake and Lake Namakan disclosed that these fish were so heavily infested that the State Department of Agriculture, Dairy and Food barred the sale of these fish for human consumption in Minnesota. This action was taken to save the fishermen unnecessary expense as well as to spare the fishing industry from detrimental public reactions. Infestation occurred in 70 to 100 per cent of the fish examined and often as many as 25 worms would be found in a single fish.

Continuing investigations revealed, in the summer of 1932, that the infestation of herring had decreased slightly in Lake Superior. The results obtained from examination of various lots of herring disclosed that a very fair percentage of these fish would now pass within the Food and Drug Administration's established range of tolerance. To provide a system for the selecting of marketable fish from the catches of the fishermen, the Minnesota Department of Agriculture, Dairy and Food, with the cooperation of the herring fishermen of Lake Superior, established its first inspection service depot which was located in the city of Duluth on Lake Superior.

Studies were continued in Lake Superior and the International Lakes, and the Duluth inspection depot was operated continuously after 1932. In 1939 studies disclosed an improvement in the condition of tullibees in Lake of the Woods that would allow a considerable percentage of the tullibees of 16 ounces and less in weight from certain locations in the lake to pass inspection. Consequently, the State opened its second fish inspection station, at Warroad, in 1939. In 1940 various other points on Lake of the Woods were equipped with facilities for inspection.

The Minnesota system of inspection utilizes identical practice for both herring and tullibees. Ten fish are taken from each individual catch and carefully examined for the cysts of *Triaenophorus robustus*. The lots of fish found to be sufficiently free of infestation to fall within the margin of tolerance allowed by the Food and Drug Administration are approved for marketing. Fish so approved are also inspected for quality and graded, and if found to be of No. 1 quality, are given a certificate of inspection and tagged "Minnesota No. 1 fish". Inspection service is maintained at the expense of the fishing industry, through payment of a 7 cent fee to cover the inspection of each 100 pounds of fresh fish or a 110-pound keg of cured fish. Boxes containing fish that pass inspection are all tagged with the Minnesota certicate of inspection. Fish that fail to pass inspection are either used for fillets or sold to fur farmers for animal food. Any fillets produced are inspected and approved by affixing a tag if found to be reasonably free of parasites.

Definite rules and regulations establishing standards for the pack of fish, the condition of fish, the packaging and icing of the fish and the labeling of the containers were promulgated in the spring of 1940. These were designed to bring about, through broadened operation of the State inspection system, the further improvement of the quality of Minnesota herring destined for the markets. These regulations, which apply to the fresh, frozen, and salted herring industry, were adopted only after their consideration by the fishermen themselves, in meetings held for this purpose.

The inspection program of the State of Minnesota has approved large quantities of high quality fish for the Nation's markets. It has also discarded as unfit for sale at the point of production a sizable volume of parasitized fish. Over 566,000 pounds of herring were denied approval for use as human food in the first 10 months of operation of the Duluth station. During 1939 more than 5 million pounds of lake herring passed inspection. The year 1940 should see the marketing of over a million pounds of tullibees from Lake of the Woods.

Minnesota's fish inspection system has provided unparasitized fish for American markets. It has made Minnesota fishermen quality-conscious. It has salvaged much of what Minnesota fishermen once despaired of as lost forever. The benefits have been so thoroughly demonstrated to Minnesota's fishermen that they are solidly behind the inspection and grading service and are grateful for the efforts of the State that forced the system on them. Through these services fishermen have been enabled to obtain maximum prices for their products, consumers have obtained assurance of quality merchandise, and the fishing towns of northern Minnesota have been restored to a semblance of their former prosperity.

APPENDICES

AMERICAN FISHERIES SOCIETY
Organized 1870

Certificate of Incorporation

We, the undersigned, persons of full age and citizenship of the United States, and a majority being citizens of the District of Columbia, pursuant to and in conformity with sections 599 to 603, inclusive, of the Code of Law for the District of Columbia, enacted March 3, 1901, as amended by the acts approved January 31 and June 30, 1902, hereby associate ourselves together as a society or body corporate and certifying in writing:

1. That the name of the Society is the American Fisheries Society.

2. That the term for which it is organized is nine hundred and ninety-nine years.

3. That its particular business and objects are to promote the cause of fish culture; to gather and diffuse information bearing upon its practical success, and upon all matters relating to the fisheries; to unite and encourage all interest of fish culture and the fisheries; and to treat all questions of a scientific and economic character regarding fish; with power:

(a) To acquire, hold and convey real estate and other property, and to establish general and special funds.

(b) To hold meetings.

(c) To publish and distribute documents.

(d) To conduct lectures.

(e) To conduct, endow, or assist investigation in any department of fishery and fish-culture science.

(f) To acquire and maintain a library.

(g) And, in general, to transact any business pertinent to a learned society.

4. That the affairs, funds and property of the corporation shall be in general charge of a council, consisting of the officers and the executive committee, the number of whose members for the first year shall be seventeen, all of whom shall be chosen from among the members of the Society.

Witness our hands and seals this 16th day of December, 1910.

Seymour Bower	(Seal)
Theodore Gill	(Seal)
William E. Meehan	(Seal)
Theodore S. Palmer	(Seal)
Bertrand H. Roberts	(Seal)
Hugh M. Smith	(Seal)
Richard Sylvester	(Seal)

Recorded April 16, 1911.

CONSTITUTION AND BY-LAWS

OF THE

AMERICAN FISHERIES SOCIETY

(As Amended Sept. 6, 1940)

ARTICLE I

NAME AND OBJECT

The name of this Society shall be American Fisheries Society.

The objects of this Society shall be to promote the cause of fish culture and its allied interests; to gather and diffuse information on all questions pertaining to fish culture, fish, and fisheries; and to unite and encourage those interested in fish culture, and fisheries problems.

ARTICLE II

MEMBERSHIP

The membership of this Society shall be classified as follows: Active, Club, Libraries, State, Patron, Honorary, and Corresponding.

Active Members.—Any person may upon a two-thirds vote of the members present at any regular annual meeting and upon the payment of one year's dues become an active member of this Society. The annual dues of active members shall be three ($3.00) dollars per year, payable in advance. Any active member may upon payment of fifty ($50.00) dollars become exempt from the payment of annual dues though retaining the privileges of active membership for the duration of his life.

Club Members.—Any sporting or fishing club or society, or any firm or corporation, upon a two-thirds vote of the members present at any regular meeting and upon the payment of one year's dues, may become a club member of this Society. The annual dues of club members shall be five ($5.00) dollars per year.

Libraries.—Libraries may be admitted to membership upon a two-thirds vote of the members present at any regular meeting and the payment of one year's dues. The annual dues for libraries shall be two ($2.00) dollars per year.

State Memberships.—Any state, provincial or federal department of the United States, Canada or Mexico may become a state member of this Society upon a two-thirds vote of the members present at any regular meeting and the payment of one year's dues. The annual dues for State memberships shall be twenty ($20.00) dollars per year.

Patrons.—Any person, society, club, firm or corporation, on approval of the Executive Committee and the payment of fifty ($50.00) dollars or more, may become a patron, and shall be listed in all the published membership lists of the Society.

Honorary and Corresponding Members.—Any person may be made an honorary or corresponding member of this Society upon a two-thirds vote of the members present at any regular annual meeting of the Society. The President of the United States, the President of Mexico, the Governors of the several states, and the Secretary of the Interior of the United States, the Governor-General of Canada,

the Lieutenant-Governors of the several Canadian provinces, and the Dominion Minister in Charge of Game and Fisheries shall be honorary members of this Society while occupying their respective official positions.

Election of Members between Annual Meetings.—The President, Secretary and Treasurer of the Society are hereby authorized to act upon all applications for memberships received while the Society is not in session.

Rights and Duties of Members.—Active members in good standing only shall have the right to vote at regular or special meetings of the Society. Any member is held to be in good standing whose dues are not more than one year past due. In case of non-payment of dues for one year, proper notice shall be given the member by the Treasurer in writing, and if such member remains delinquent one month from the date of such notice, his name shall be dropped from the roll of the Society. Such delinquent member, having been dropped for non-payment of dues, shall be ineligible for election as a new member for a period of one year, except upon payment of arrears and current dues. Each member of the Society in good standing, except honorary members, shall receive one copy of the annual volume of Transactions.

Quorum.—Twenty voting members shall constitute a quorum for the transaction of business at annual or other meetings of the Society.

ARTICLE III

Funds

Current Fund.—All moneys received from the payment of dues of active members, club members, libraries, life members, state members, sale of Transactions, contributions thereto, and from any miscellaneous sources, shall be credited to the Current Fund of the Society and shall be paid out only on vouchers regularly approved by the President and Secretary.

Permanent Fund.—The President, Secretary and Treasurer shall be the Trustees of the Permanent Fund. All moneys received from patrons, bequests and contributions thereto shall be credited to the Permanent Fund of the Society. Such fund shall be invested by the Treasurer in such manner as may be approved by the trustees of such fund. The members of the Society shall, at each annual meeting, determine the disposition of interest accruing from such investment.

ARTICLE IV

Officers

The officers of this Society shall be a president, a first vice-president, and a second vice-president, all of whom shall be elected for the term of one year and shall be ineligible for reelection to the same office until a year after the expiration of their terms; a secretary, a treasurer, a librarian, and five vice-presidents, one to be in charge of each of the following divisions or sections:

1. Fish Culture.
2. Commercial Fishing.
3. Aquatic Biology and Physics.
4. Angling.
5. Protection and Legislation.

The officers specified above, and the president of the previous year, shall form

an Executive Committee* with authority to decide the policies of the Society and to transact such business of the Society as may be found necessary. The Executive Committee is authorized to fill from the membership any vacancies that may occur in any offices between meetings. A majority of the Executive Committee shall constitute a quorum.

Only members in good standing who are in attendance or have been in attendance at one of the two immediately preceding meetings shall be eligible for election to the offices listed above and for appointment to any committee, except the members of the Committee on Common and Scientific Names of Fishes.

The officers shall be elected by a majority vote at a regular meeting, a quorum being present.

No officer of this Society shall receive any salary or compensation for his services and no allowances shall be made for clerical services except by vote of the Society at regular annual meetings.

Duties of Officers.—The President shall preside at the regular and all special meetings of the Society and shall be ex-officio chairman of the Executive Committee.

The first Vice-President shall act in the place of the President in case of absence or inability of the latter to serve.

The Secretary shall keep the records of the Society, conduct its correspondence, promote its membership, and arrange for regular and special meetings. The Secretary shall also attend to the publication and distribution of the annual issuance of Transactions.

The Treasurer shall receive and collect all dues and other income of the Society, shall have the custody of its funds and pay all claims which have been duly approved. The Treasurer shall furnish a bond in the sum of seven thousand, five hundred ($7,500) dollars to be approved by the Executive Committee and to be paid for by the Society. The offices of Secretary and Treasurer may be occupied by the same person.

The Librarian shall have the custody of the library of the Society, including its permanent records and printed Transactions, and shall have charge of the sale of surplus copies of such Transactions.

The Vice-President of each division shall become conversant with the subject of his division and present a report on it at the regular meeting, placing emphasis upon developments during the past year.

Committee members shall cooperate in performing the functions of their appointments and render reports as directed by the President.

ARTICLE V

Standing Committees

The standing committees shall be Executive; International Relations; State and National Relations; Common and Scientific Names of Fishes; and Publications. The Committee on Publications shall be appointed by the President. The Executive Committee shall be selected as provided for by Article IV.

The Committee on International Relations shall be composed of seven members selected by the nominating committee for election, and its duties shall be to exchange ideas pertaining to the various phases of fisheries administration, biology, including fish culture, with foreign fishery biologists, conservation and fishery administration officials, fish-culturists or aquicultural societies. A report based on such exchange should be presented at each regular meeting.

The Committee on State and National Relations shall be composed of five members selected by the nominating committee for election, and its duties shall be to act in behalf of the Society as a coordinating and advisory board for the consideration of interstate and National-State fishery problems. A report shall be presented at each annual meeting.

*The Council was discontinued and the Executive Committee enlarged by Amendment to By-Laws, September 11, 1935.

The Committee on Common and Scientific Names of Fishes shall be composed of seven members selected by the nominating committee for election. Its duties shall be to establish and maintain in the files of the Librarian of this Society a correct check list of the species of fishes occurring in the waters of the United States and Canada. This list should contain both scientific and common names.

The Committee on Publications shall be composed of five members, and its duties shall be to select and edit manuscripts submitted for publication. Papers shall be submitted ready for publication within thirty days after the close of the regular meeting. Such papers, together with the minutes of the regular and special meetings and the reports of the various divisions and committees, shall be published in an annual volume which shall be numbered in series with previous volumes and entitled: TRANSACTIONS OF THE AMERICAN FISHERIES SOCIETY.

ARTICLE VI

Meetings

The regular meeting of the Society shall be held once a year, the time and place to be decided upon at the preceding meeting, or, in default of such action, by the Executive Committee. Special meetings shall be called by the President upon approval of a majority of the Executive Committee.

ARTICLE VII

Order of Business

1. Call to order by the President.
2. Roll call of members.
3. Application for memberships.
4. Reports of officers:
   a. President
   b. Secretary
   c. Treasurer
   d. Vice-Presidents of Divisions
   e. Standing Committees
   f. Special Committees
5. Committees appointed by the President:
   a. Committee of five on nomination of officers and standing committees for the ensuing year.
   b. Committee of five on time and place of next meeting.
   c. Committee of five on resolutions.
   d. Auditing committee of three.
   e. Committee of three on program.
   f. Committee of three on publicity.
   g. Committee of five on publications.*
6. Reading of papers and discussions of same. In the reading of papers preference shall be given to the members present.
7. Miscellaneous business.
8. Adjournment.

ARTICLE VIII

Changing By-Laws

The By-Laws of the Society may be amended, altered or repealed by a two-thirds vote of the members present at any regular meeting, provided at least twenty-five members are present at said regular meeting.

*A resolution adopted August 24, 1937 established a staggered committee of five and provided that each incoming President shall appoint one new member for a term of five years and designate the Chairman of the Committee.

AMERICAN FISHERIES SOCIETY

LIST OF MEMBERS

(Showing year of election to membership)

HONORARY MEMBERS

The President of the United States.
The President of Mexico.
The Secretary of the Interior of the United States.
The Governors of the several States.
The Governor-General of Canada.
The Lieutenant-Governors of the several Canadian Provinces.
The Dominion Minister in Charge of Game and Fisheries.
'08 Antipa, Prof. Gregoire, Inspector-General of Fisheries, Bucharest, Roumania
'06 Besana, Giuseppe, Lombardy Fisheries Society, Via Rugabello 19, Milan, Italy
'09 Blue Ridge Rod and Gun Club, Harper's Ferry, W. Va.
'04 Denbigh, Lord, London, England.
'40 Gordon, Seth, % Game Commission, Harrisburg, Pa.
'09 Nagel, Hon. Chas., St. Louis, Mo.
'08 Nordqvist, Dr. Oscar Fritjof, Superintendent of Fisheries, Lund, Sweden.

PATRONS

'14 Alaska Packers Association, San Francisco, Calif.
'15 Allen, Henry F. (Agent Crown Mills), 210 California St., San Francisco, Calif.
'15 American Biscuit Co., 815 Battery St., San Francisco, Calif.
'15 American Can Co., Mills Building, San Francisco, Calif.
'15 Armour & Co., Battery and Union Sts., San Francisco, Calif.
'15 Armsby, J. K., Company, San Francisco, Calif.
'15 Atlas Gas Engine Co., Inc., Foot of 22nd Avenue, Oakland, Calif.
'15 Balfour, Guthrie & Co., 350 California St., San Francisco, Calif.
'15 Bank of California, N. A., California and Sansome Sts., San Francisco, Calif.
'15 Bloedel-Donovan Lumber Mills, Bellingham, Wash.
'15 California Barrel Co., 22d and Illinois Sts., San Francisco, Calif.
'15 California Door Co., 43 Main St., San Francisco, Calif.
'15 California Stevedore & Ballast Co., Inc., 210 California St., San Francisco, Calif.
'15 California Wire Cloth Company, San Francisco, Calif.
'15 Caswell, Geo. W., Co., Inc., 503-4 Folsom St., San Francisco, Calif.
'15 Coffin-Redington Co., 35-45 Second St., San Francisco, Calif.
'15 Columbia River Packers Association, Astoria, Ore.
'15 Crane Co., C. W. Weld, Mgr., 301 Brannon St., San Francisco, Calif.
'15 First National Bank of Bellingham, Bellingham, Wash.
'15 Fuller, W. P., & Co., 301 Mission St., San Francisco, Calif.
'15 Grays Harbor Commercial Co., Foot of 3d St., San Francisco, Calif.
'15 Jones-Thierbach Co., The, Battery and Merchant Sts., San Francisco, Calif.
'15 Knapp, The Fred H., Co., Arcade-Maryland Casualty Building, Baltimore, Md.
'15 Linen Thread Co., The, W. A. Barbour, Mgr., 443 Mission St., San Francisco, Calif.
'15 Morrison Mill Co., Inc., Bellingham, Wash.
'15 Morse Hardware Co., Inc., 1025 Elk St., Bellingham, Wash.
'15 Pacific Hardware & Steel Co., 7th and Townsend Sts., San Francisco, Calif.
'15 Pacific States Electric Co., 575 Mission St., San Francisco, Calif.
'15 Pope and Talbot, Foot of 3d St., San Francisco, Calif.

'15 Puget Sound Navigation Co., Seattle, Wash.
'15 Ray, W. S. Mfg. Co., Inc., 216 Market St., San Francisco, Calif.
'15 Schmidt Lithograph Co., 2d and Bryant Sts., San Francisco, Calif.
'15 Schwabacher-Frey Stationery Co., 609-11 Market St., San Francisco, Calif.
'15 Sherwin-Williams Co., The, 454 Second St., San Francisco, Calif.
'15 Ship Owners' and Merchants' Tug Boat Co., Foot of Green St., San Francisco, Calif.
'15 Smith Cannery Machine Co., 2423 South First Avenue, Seattle, Wash.
'15 Standard Gas Engine Co., Dennison and King Sts., Oakland, Calif.
'15 Standard Oil Co. of California, Standard Oil Building, San Francisco, Calif.
'15 U. S. Rubber Co. of California, James B. Brady, Gen. Mgr., 2nd and Folsom Sts., San Francisco, Calif.
'15 U. S. Steel Products Co., Rialto Building, San Francisco, Calif.
'15 Wells Fargo National Bank of San Francisco, Montgomery and Market Sts., San Francisco, Calif.
'15 Western Meat Co., 6th and Townsend Sts., San Francisco, Calif.
'15 White Bros., 5th and Brannon Sts., San Francisco, Calif.

LIFE MEMBERS

'00 Beeman, Henry W., New Preston, Conn.
'13 Belding, Dr. David L., 80 East Concord St., Boston, Mass.
'80 Belmont, Perry, 1618 New Hampshire Ave., Washington, D. C.
'97 Birge, Dr. E. A., University of Wisconsin, Madison, Wis.
'04 Buller, A. G., Pennsylvania Fish Commission, Corry, Pa.
'12 Buller, Nathan R., Pennsylvania Fish Commission, Harrisburg, Pa.
'26 Cary, Guy, 55 Wall St., New York, N. Y.
'04 Coker, Dr. Robert E., University of North Carolina, Chapel Hill, N. C.
'01 Dean, Herbert D., Northville, Mich.
'15 Folger, J. A., Howard and Spencer Sts., San Francisco, Calif.
'12 Fortmann, Henry F., 1007 Gough St., San Francisco, Calif.
'26 Goelet, Robert W., 18 East 47th St., New York, N. Y.
'22 Grammes, Charles W., Hamilton Park, Allentown, Pa.
'03 Gray, George M., Marine Biological Laboratory, Woods Hole, Mass.
'28 Hall, W. A., Co., Gardiner, Mont.
'10 Hopper, George L., Havre De Grace, Md.
'23 Kienbusch, C. O., 12 E. 74th St., New York, N. Y.
'22 Kulle, Karl C., Suffield, Conn.
'26 Lackland, Sam H., 69 So. Ann St., Mobile, Ala.
'26 Low, Ethelbert I., 256 Broadway, New York, N. Y.
'15 Mailliard, Joseph, 1815 Vallejo St., San Francisco, Calif.
'99 Morton, W. P., 105 Sterling Ave., Providence, R. I.
'16 Nelson, Charles A. A., Lutsen, Minn.
'07 Newman, Edwin A., 4205 8th St., N. W., Washington, D. C.
'31 Nicholas, E. Mithoff, 20 S. 3d St., Columbus, Ohio.
'10 Osburn, Prof. Raymond C., Ohio State University, Columbus, Ohio.
'04 Palmer, Dr. Theodore S., 1939 Biltmore St., N. W., Washington, D. C.
'10 Radcliffe, Dr. Lewis, 5600 32nd St., N. W., Washington, D. C.
'05 Safford, W. H., 229 Wing St., S., Northville, Mich.
'00 Thompson, W. T., 121 N. Willson, Bozeman, Mont.
'13 Timson, William, Alaska Packers' Association, San Francisco, Calif.
'12 Townsend, Dr. Charles H., New York Aquarium, New York, N. Y.
'11 Valette, Luciano H., Echevarria F. C. S., Buenos Aires, Argentina, S. A
'22 Walcott, Frederic C., Norfolk, Conn.
'98 Ward, Dr. Henry B., 1201 Nevada St., Urbana, Ill.
'97 Wood, Colburn C., Box 355, Plymouth, Mass.

ACTIVE MEMBERS

'35 Adams, Harry E., Sabine Migratory Waterfowl Refuge, Sulphur, La.
'33 Adams, Milton P., 638 Sunset Lane, East Lansing, Mich.
'13 Adams, William C., Dept. of Conservation, Albany, N. Y.
'29 Ainsworth, A. L., Tuxedo Fisheries, Tuxedo Park, N. Y.
'33 Albert, W. E., Jr., Lansing, Iowa.
'38 Alderson, I. T., Von Hoffman Press, 101 S. 9th St., St. Louis, Mo.
'31 Aldrich, A. D., 2879 East Archer, Tulsa, Okla.
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(REVISED 1941)

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JOHN EDWARD DOE
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8. **Underscore** (italics) all scientific names of genera and species, both animals and plants, in both text and tables. Do not underscore or use all capital letters for scientific names of a category higher than the genus: Esocidae; *Esox lucius. Do not underscore any words unless italics are intended.*

9. Inspect papers in the last volume of the Transactions if you have questions concerning the arrangement of materials.

II. STYLE

10. **Bibliographic references** in text should give name of author and year of publication in parentheses, thus (Doe, 1932). Do not use letters or numbers or footnotes for references. If more than one publication by the same author is given for a year, use the alphabet to designate the correct paper, thus (Doe, 1932a) or (Doe, 1932b). In the bibliography do not repeat the author's name if reference is made to more than one of his publications, but list his publications in chronological order beginning with the earliest one. In citing a joint publication invert the name of the senior author but not of the co-author or co-authors. *Do not include any references not mentioned in the text.* List authors in alphabetical sequence. Capitalize the first word and proper names only in the title. Follow the arrangement given below to be placed at end of paper:

Literature Cited

Doe, John C., J. W. Brown, and H. W. Green.
1939. Report on the diseases of brook trout. Trans. Am. Fish Soc., 1938, Vol. 68, pp. 450-461.

Note that the year of publication precedes the title and the year of the meeting is stated in the reference.

Please check your references carefully as to titles, spelling, capitalization, italics, diacritical marks, abbreviations, etc., against their original sources, after the final typing, and *state beneath your bibliography that you have done so.* Many bibliographic titles published in the Transactions have been found to be incomplete and very inaccurate. Help us correct this situation.

11. **Tables.** Every table should have a heading and must be typewritten on a separate page. Insert tables among the text pages near the points where they are discussed. In preparing tables please be certain that they are not too large to appear on a single printed page. Number tables consecutively with Arabic, not Roman, numerals (1, 2, 3, etc.). Abbreviate the word 'number" (No.) when referring to a special number—not when referring to quantity or things. Spell all other words in tables, including such words as "millimeters," "ounces," and "average" (except months *with date*, in body of table), and capitalize, as a rule, the first word only in headings in the first column or over other columns. Precede all decimal numbers with zero. Use dollar sign only with first number at top of column and under each cross rule.

Item	Number of fish	Percentage of total	Average length in millimeters	Months	Cost of diet per pound
Brook trout surviving experiment No. 2	23	5.8	6.5	April-September	$0.05

12. **Capitals.** Capitalize words when used as part of a proper name or of an identifying number or letter, or when referring to a particular State, Government, and to organized bodies, or when used as proper names. For example: Lake Michigan, State of Michigan, or the State, the Province, the Republic, or the National and State Governments, Washtenaw County, Ann Arbor Township, Huron River, Pacific Ocean, North Atlantic, Northern States, Reservoir No. 1, Boulder Dam, Pond No. 1 or Pond A, State Fish Farm No. 1, Pisgah National Forest, American Fisheries Society.

Capitalize names of sections of the United States, or of any other country, as Middle West, but lower-case a term prefixed to any such sections, as eastern North Atlantic States.

Capitalize any term (except page or pages and age group) preceding Roman numerals, as Article I, Chapter II, Sample VI, etc. Also capitalize such terms as Appendix 1 or Appendix A, Experiment 2, Table 4, and Figure 8 (referring to illustrations).

Use lower case for scientific and common names of species. Capitalize scientific names of genera and higher categories.

13. **Abbreviations.**

(a) Abbreviate the following:

Clock time, if connected with figures—2:30 a.m.

Temperatures—F. (Fahrenheit).

Degrees, whether referring to temperatures, longitude and latitude, or angles, etc.—75°, 75° F., 75° C.

"*Number*," when preceding figures—No. 125; otherwise spell out.

"*United States*," if preceding name of a department or a bureau or a vessel, etc.—U. S. Department of the Interior, U. S. S. *Indiana*.

Months, in body of tables and footnotes to same when followed by day of month—Apr. 5-Sept. 2 (but April-September).

(b) Do not abbreviate the following:

States, cities, etc.

Months, in text or in headings of tables—April 5-September 2.

Measures and weight, except p.p.m.—6 inches, 20 millimeters, 5 ounces, 1.5 acres, etc.

Percentage—12 per cent, a percentage of 25.5.

14. **Numerals.** Spell out all *isolated* numbers less than 10, but use figures in a group of enumerations when any one number of that group is 10 or greater. Do not spell out numbers of two or more digits (except round numbers of approximations: estimated at five hundred; a thousand fish), and always use a comma in a number of four or more digits. Treat alike all numbers in a series of connected groups. For example: There were nine trout. There were 9 trout, 120 bass, and 50 pike.

Use figures for all enumerations of quantities and measurements, such as dimension, weight, area, volume, distance (if fraction spell out, as one-half mile), clock time, time, money, percentage, degrees, proportion or ratios, age, dates, page numbers, decimals, and mixed numbers (spell out common fractions if alone: one-eighth inch). For example: $3.00 per 20 pounds; 5 feet 6 inches; about 10 miles; 6 acres; 15 cubic centimeters; 4:30 p.m.; fish died in 1 hour and 20 minutes at 30

minutes past 4 o'clock; 25.5 per cent; 75° F.; 1:10,000; trout 2 years 6 months old; 2-year-old trout; June 29, 1936; the 1st of January, 1938, the 20th day of March; 1937-38; 4.5 p.p.m.; 0.25; 1½ pages; page 215.

Write 8 by 12, not 8 x 12 unless multiplication is indicated. Write 50-50, not "fifty-fifty."

Do not use two figures when two numbers appear together, unless the first enumeration exceeds 100: ten 12-room houses; twenty 6-inch trout; 120 6-inch trout.

Spell out figures beginning a sentence, but avoid such use of numerals if possible. Spell out both numbers of two related amounts at the beginning of a sentence in such expressions as "Twenty to twenty-five trout," but write "Two hundred fifty bass and 325 trout were shipped."

Spell out such indefinite expressions as the following: Between two and three hundred fish; there were thirty or forty thousand trout.

In expressing large numbers the word *million* (or a similar larger group term) may be spelled out: 20 million, 2¾ billions.

15. **Use of hyphen.** Many compound words when used as nouns are not hyphenated but require use of the hyphen when used as adjectives. For example note the following sentences: "This was *cold water.*" "Trout are *cold-water* fish." Write "fish culture," but "fish-culturist." Check your manuscript carefully for use of hyphen. The words, "subspecies," "upstream" and many other words originally of compound derivation are written without a hyphen.

Write "largemouth" and "smallmouth" as one word when referring to black bass.

III. SUBJECT MATTER

16. **Condense your paper** to the limit and omit all needless verbiage to reduce cost of printing. The manuscript should be simple, direct, clear, concise, accurate, consistent, and complete. *Accuracy* in subject matter, in scientific names, and in bibliography is especially important. Have your associates read and criticize your paper before the final typing. **Papers which are too poorly written will be rejected.** Do not expect your editorial committee to rewrite your manuscript.

17. **Be definite in references to species.** The scientific name, and wherever needed the *complete* common name, that will identify the species about which the paper is written should be included in the title as well as in the text, unless the number of species is too large. Such names as "bass," "trout," "pike," and "pickerel" apply to any one of several species. Do not write "smallmouth," "brook," "rainbow," etc., when you mean "smallmouth black bass," "brook trout," "rainbow trout," etc.

18. **Things to avoid.** Words that do not appear in the dictionary in the sense employed should be avoided. The *words* "case," "instance," "show," "found," "gave," and "present" are overworked in manuscripts, the same word sometimes appearing several times in one paragraph.

Avoid the repeated use of *participles* which, as a rule, weaken sentences. In the following illustration note the improvement when the words in parentheses are used: "The principles underlying (that underlie) the production of beef are essentially the same as those involving (that are involved in) the production of bass."

Avoid *split infinitives.* Please check your manuscript for this exceedingly common error.

Avoid the use of *this* and *these* as substantives. Compare, for example, the following two sentences for effectiveness: "*This* was true in every *case.*" "*The mortality was high* in every *pond.*"

19. **Abstract of paper.** Give a condensed summary or brief abstract at the beginning of your paper.

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